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WO 99/02818 A1
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(58) Field of Search
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INT CL[7] E21B 33/128 43/08 43/10
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(54) Abstract Title
**Packer formed from a tubular having bistable cells**

(57) A packer (80) for use in a well bore is constructed from a tubular (90) having a region (80) formed from a number of bistable cells (23, 83). The portion (80) of the tubular (90) which is expanded to form the packer, has a seal (84) thereon. The seal (84) may be formed from an elastomer and a resin or catalyst may be employed to allow the seal (84) to harden after setting.

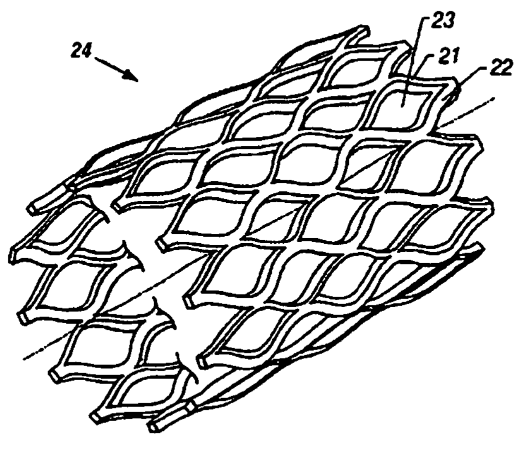


FIG. 4A

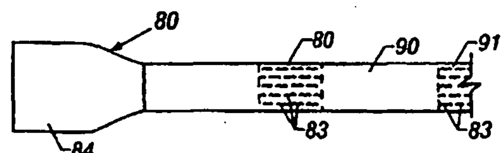


FIG. 17

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

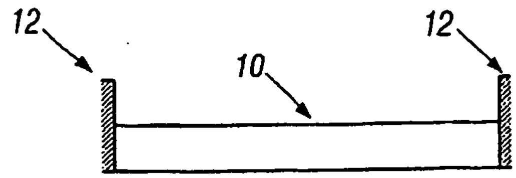


FIG. 1A

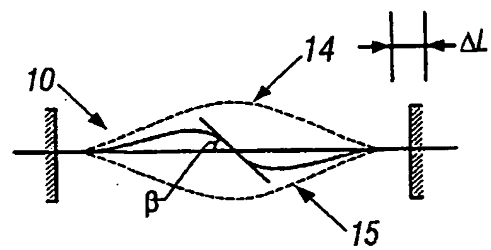


FIG. 1B

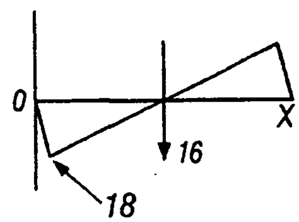


FIG. 2A

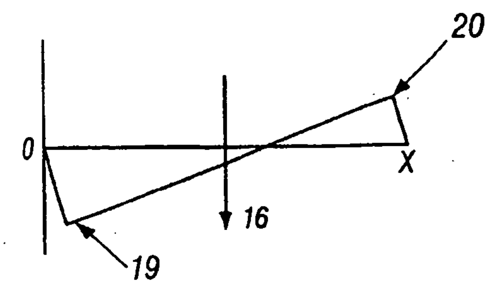


FIG. 2B

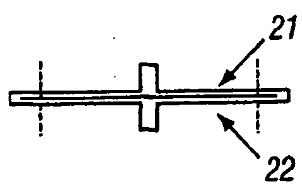


FIG. 3A

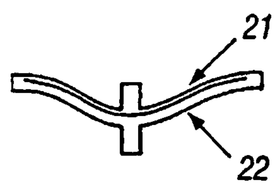


FIG. 3B

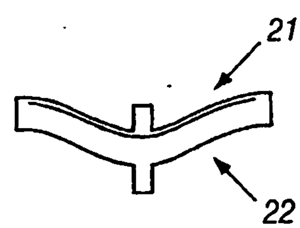


FIG. 3C

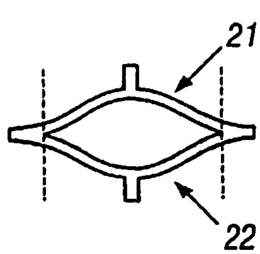


FIG. 3D

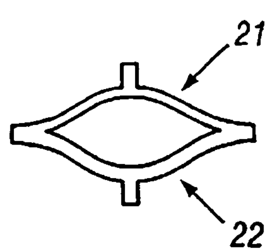


FIG. 3E

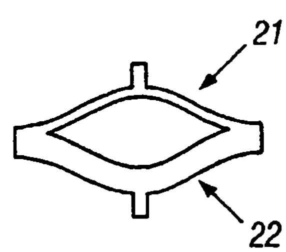


FIG. 3F

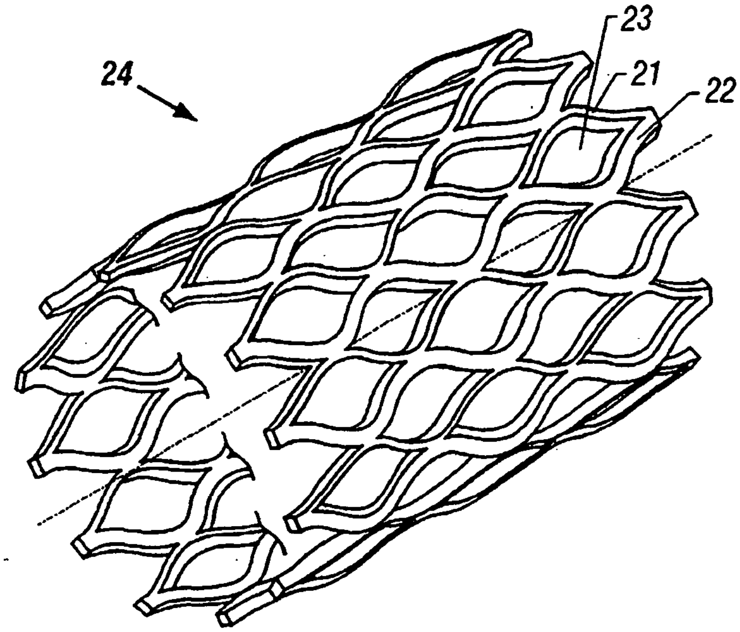


FIG. 4A

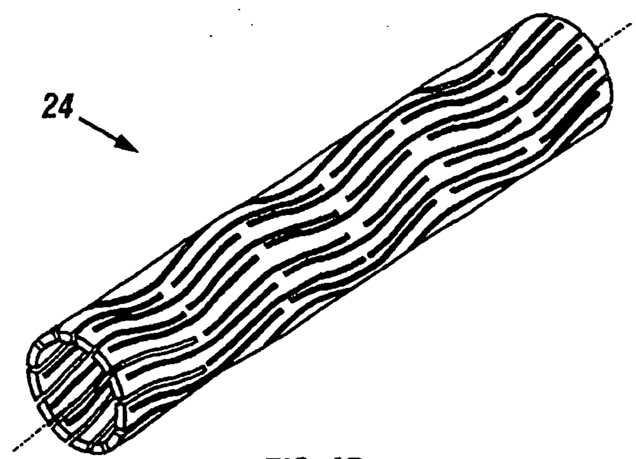


FIG. 4B

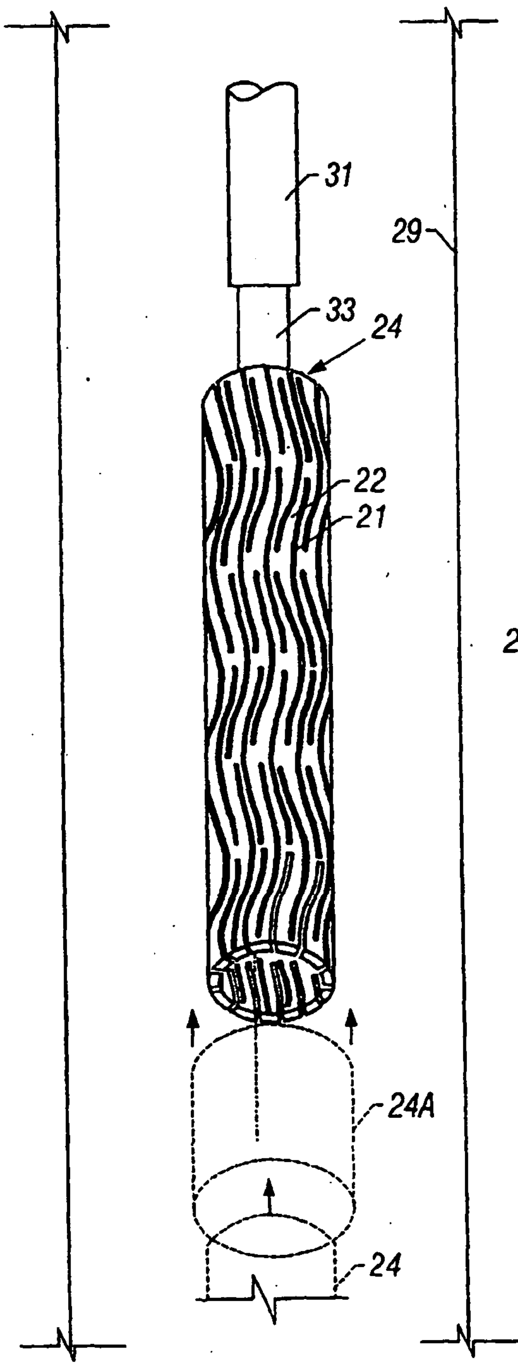


FIG. 4C

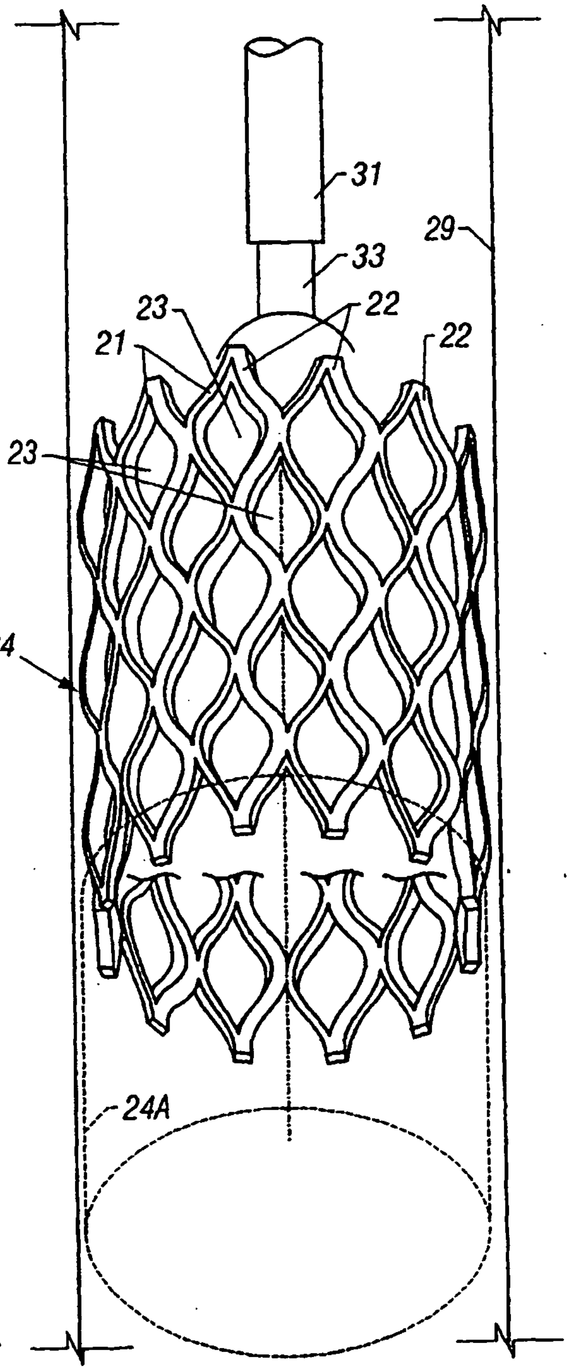


FIG. 4D

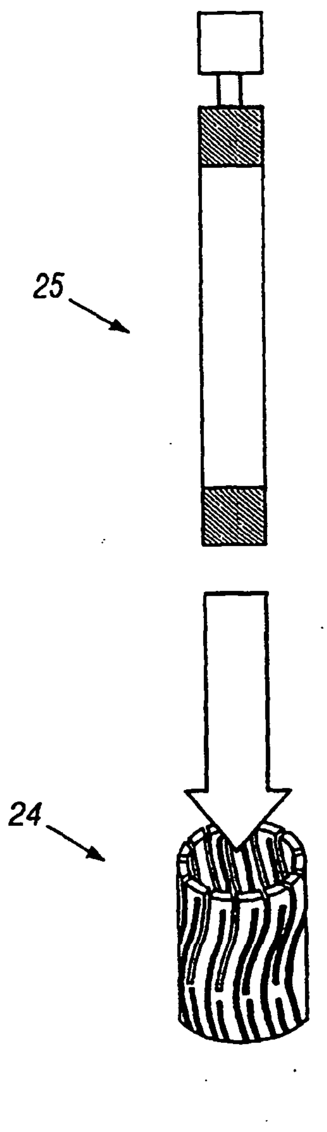


FIG. 5A

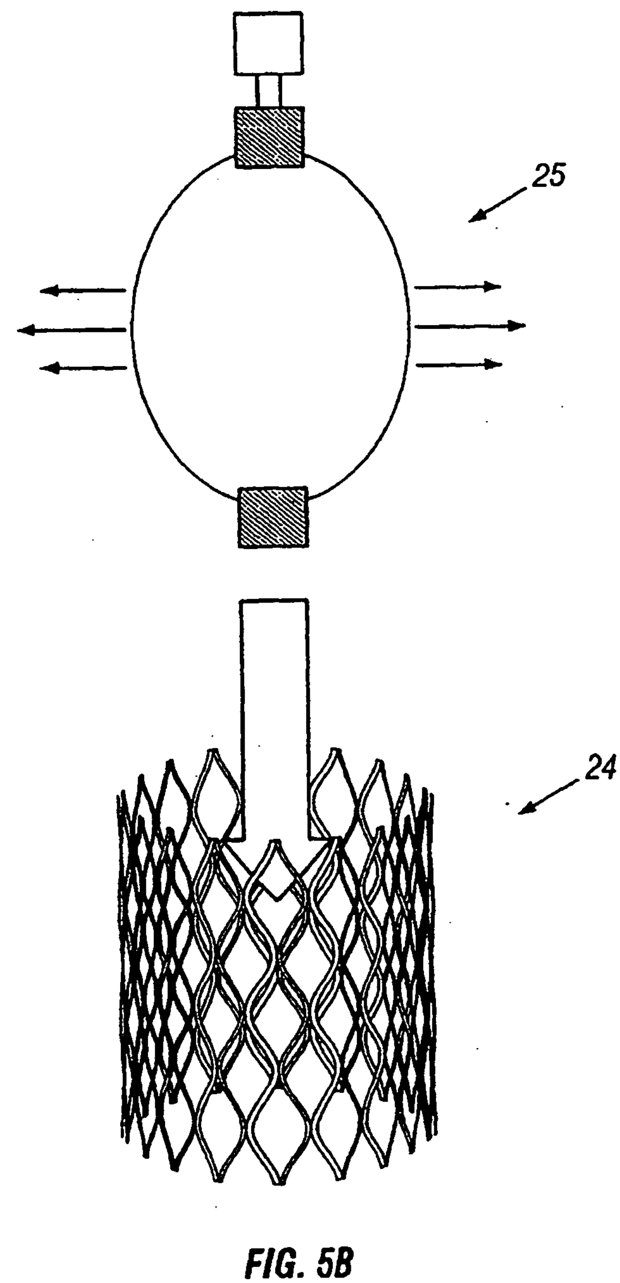


FIG. 5B

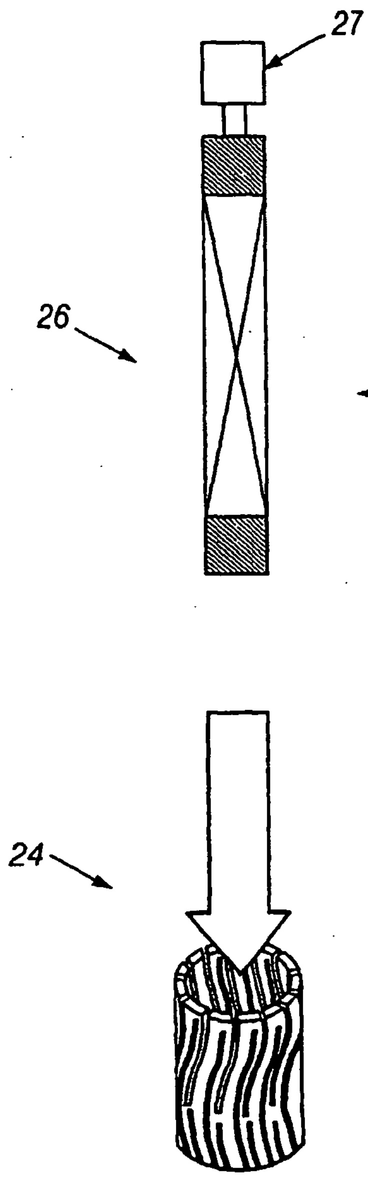


FIG. 6A

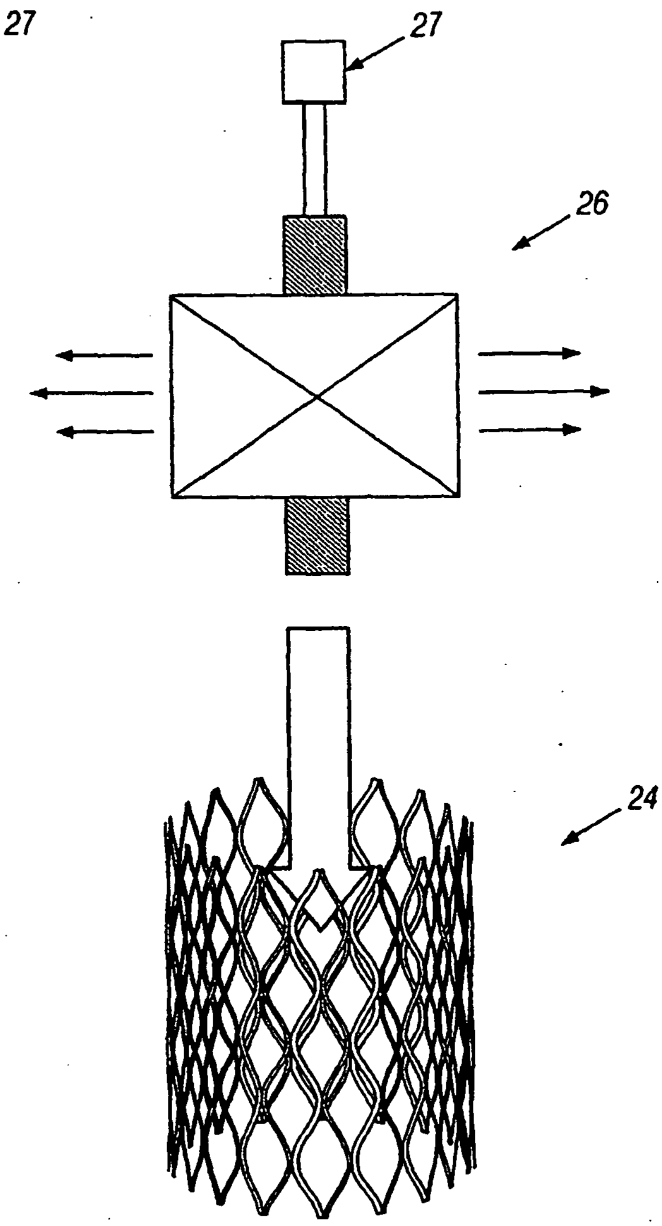


FIG. 6B

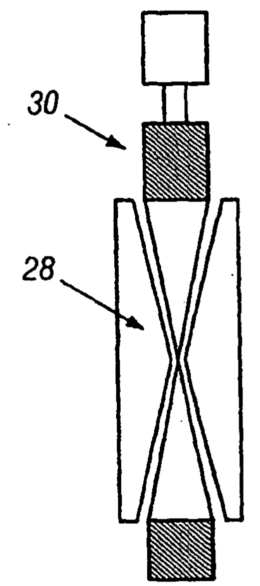


FIG. 7A

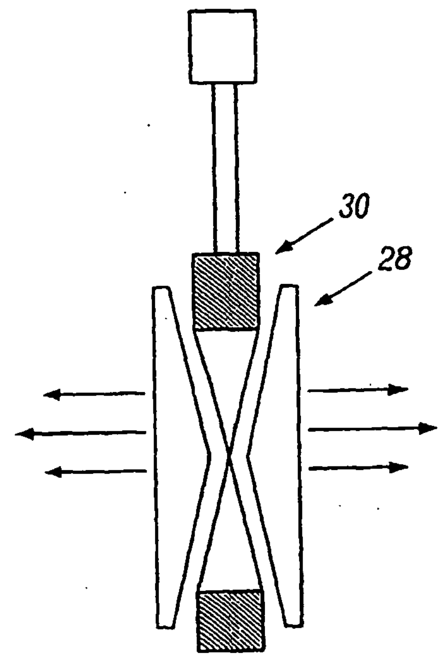


FIG. 7B

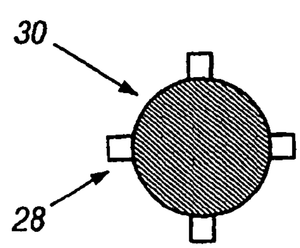


FIG. 7C

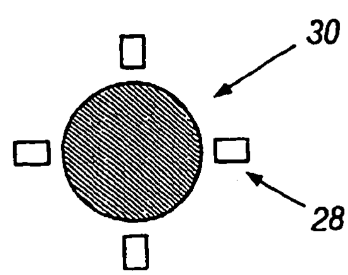


FIG. 7D

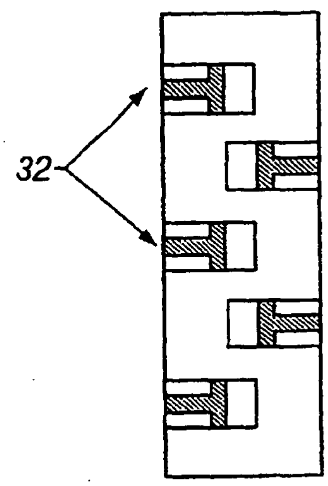


FIG. 8A

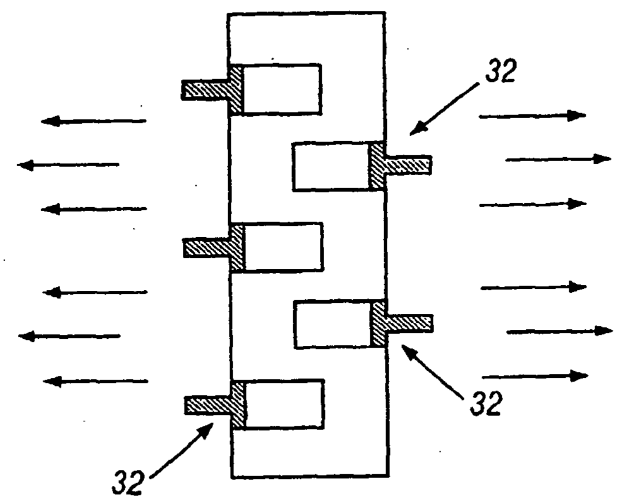


FIG. 8B

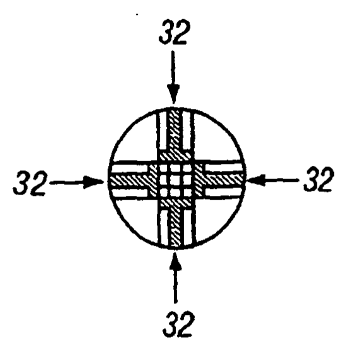


FIG. 8C

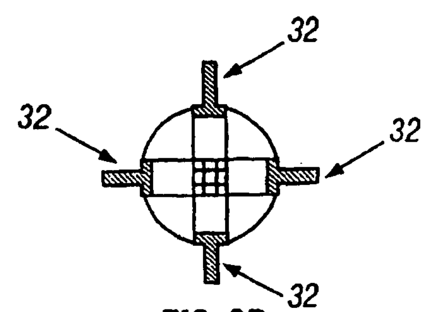


FIG. 8D

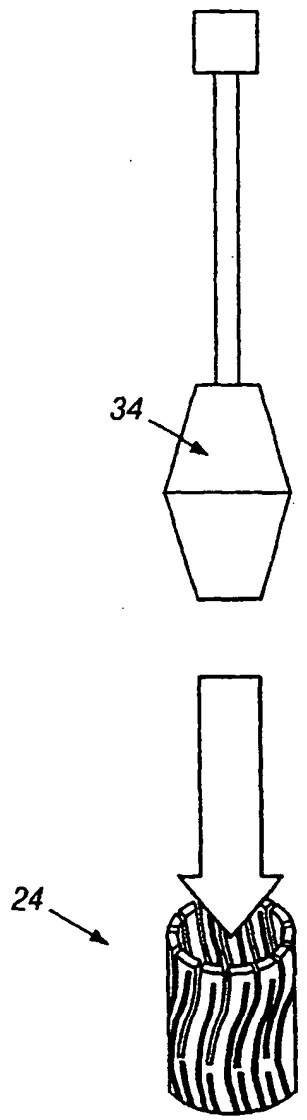


FIG. 9A

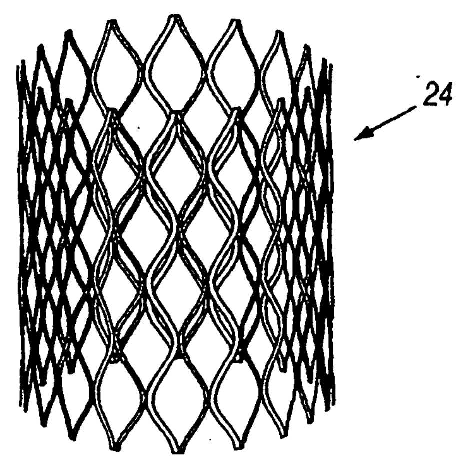


FIG. 9B

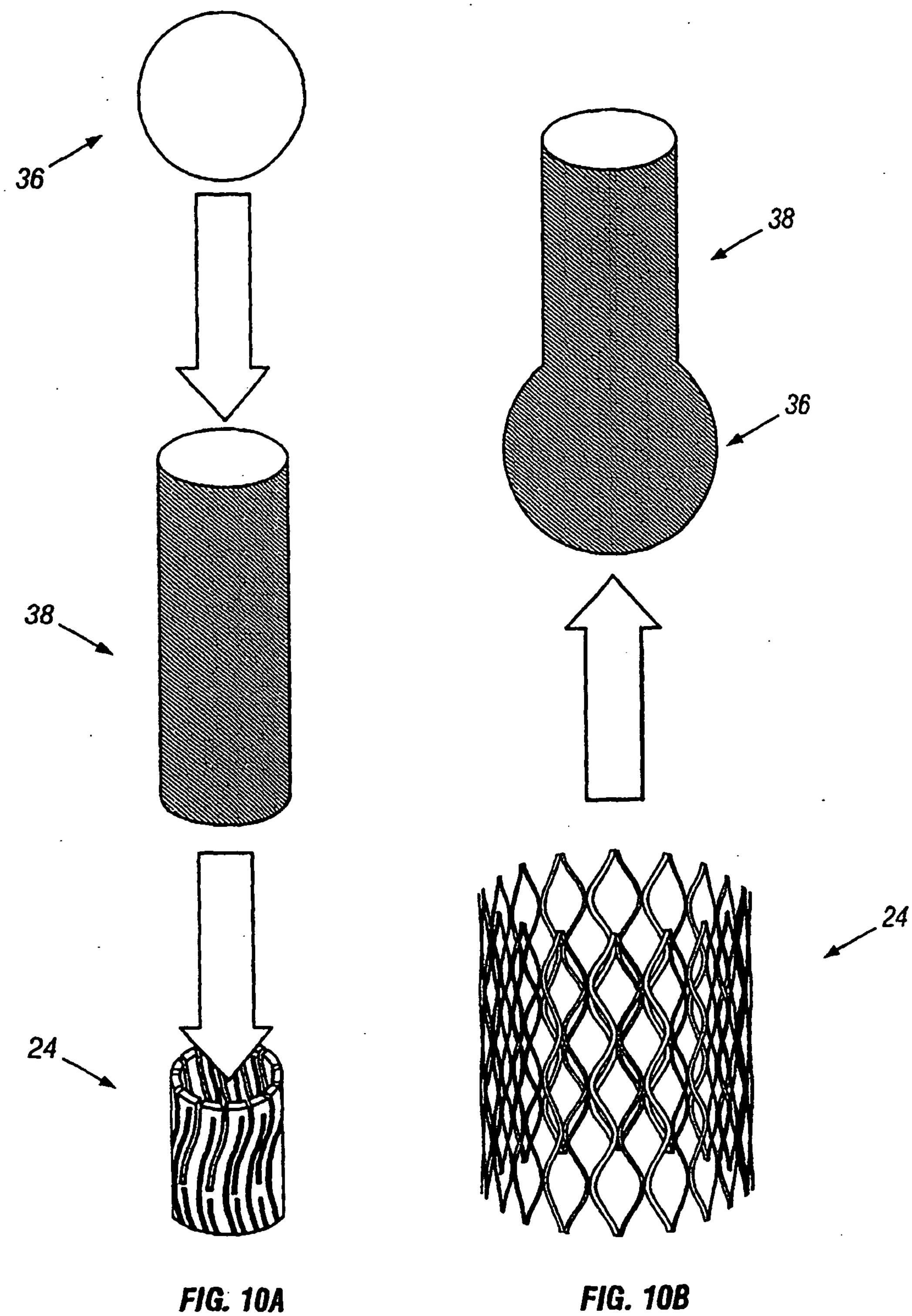


FIG. 10A

FIG. 10B

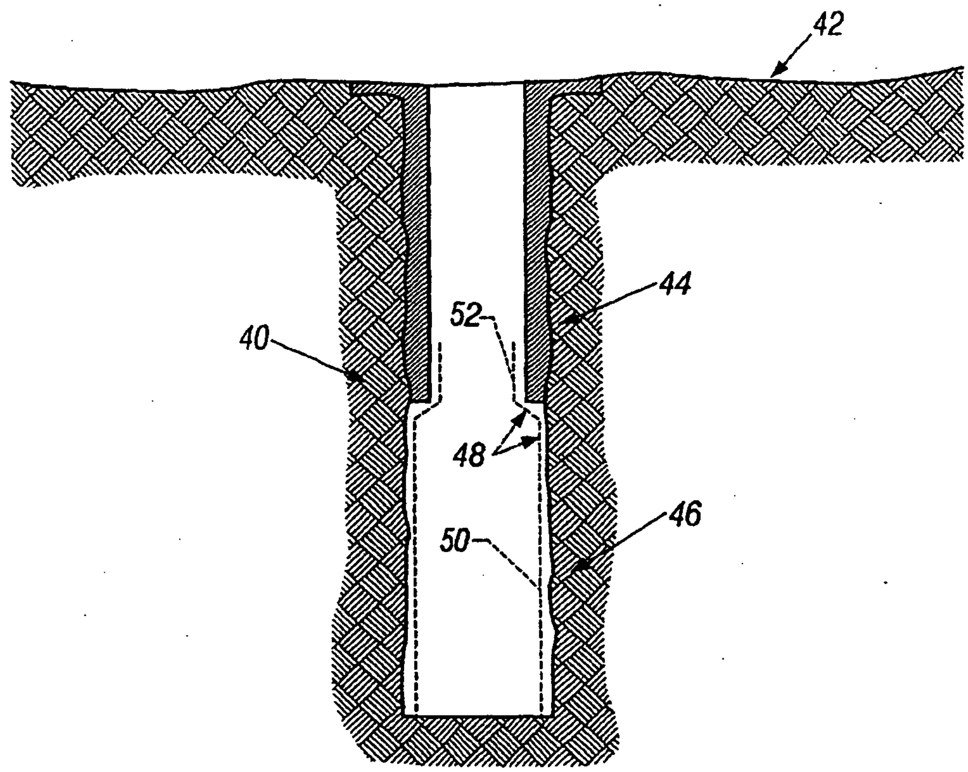


FIG. 11

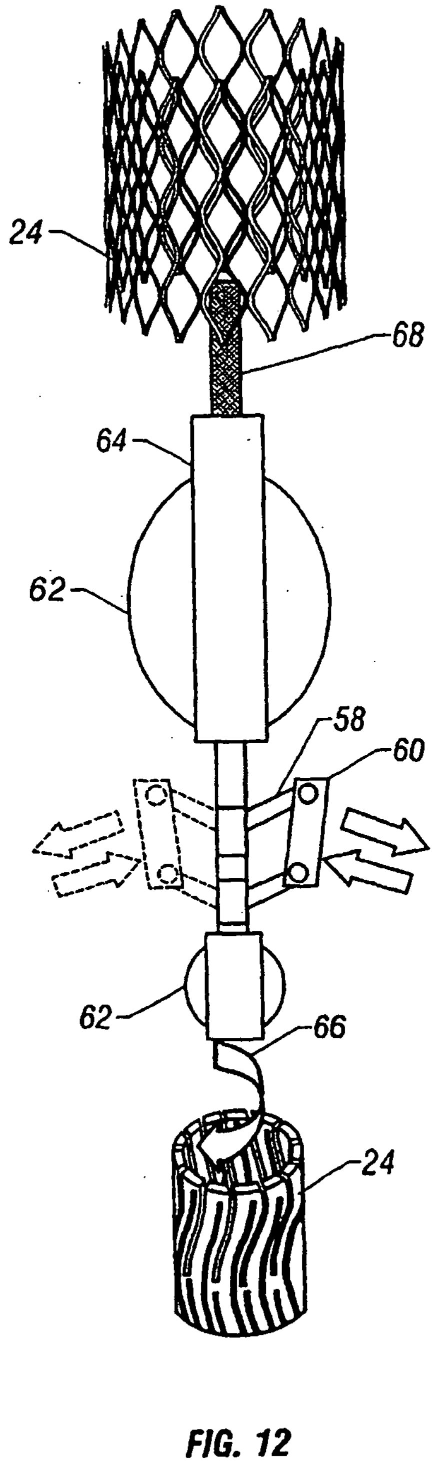


FIG. 12

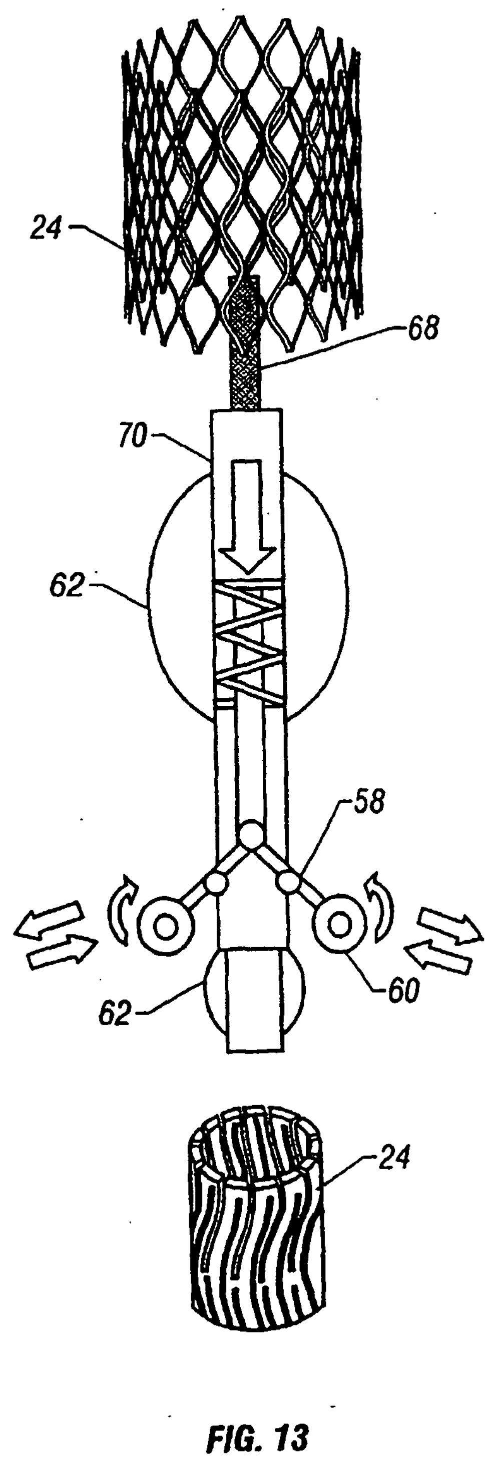


FIG. 13

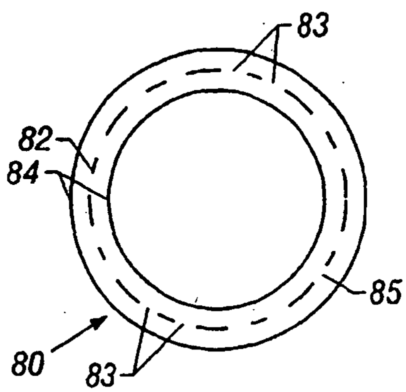


FIG. 14

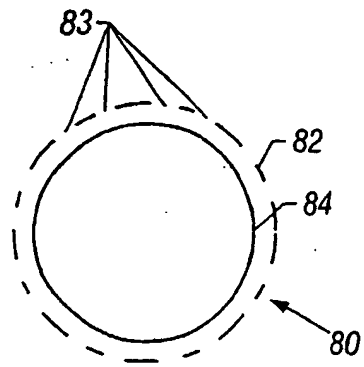


FIG. 15

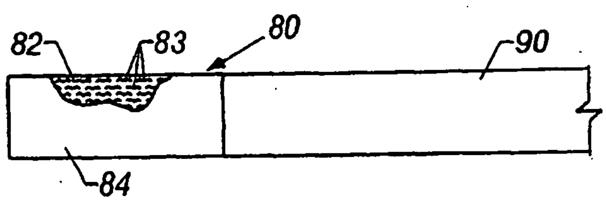


FIG. 16

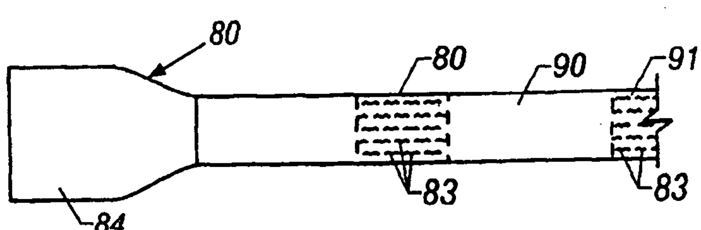


FIG. 17

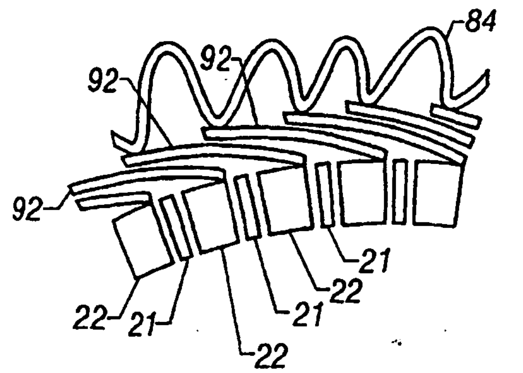


FIG. 18A

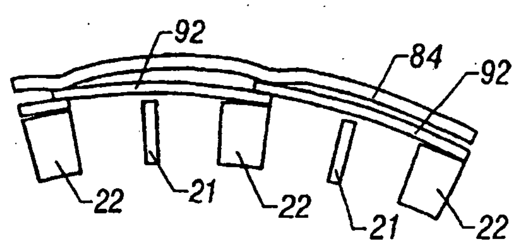


FIG. 18B

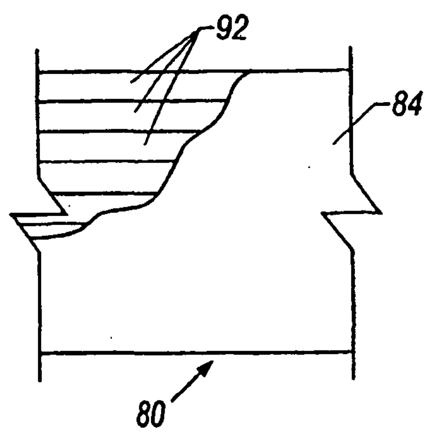


FIG. 18C

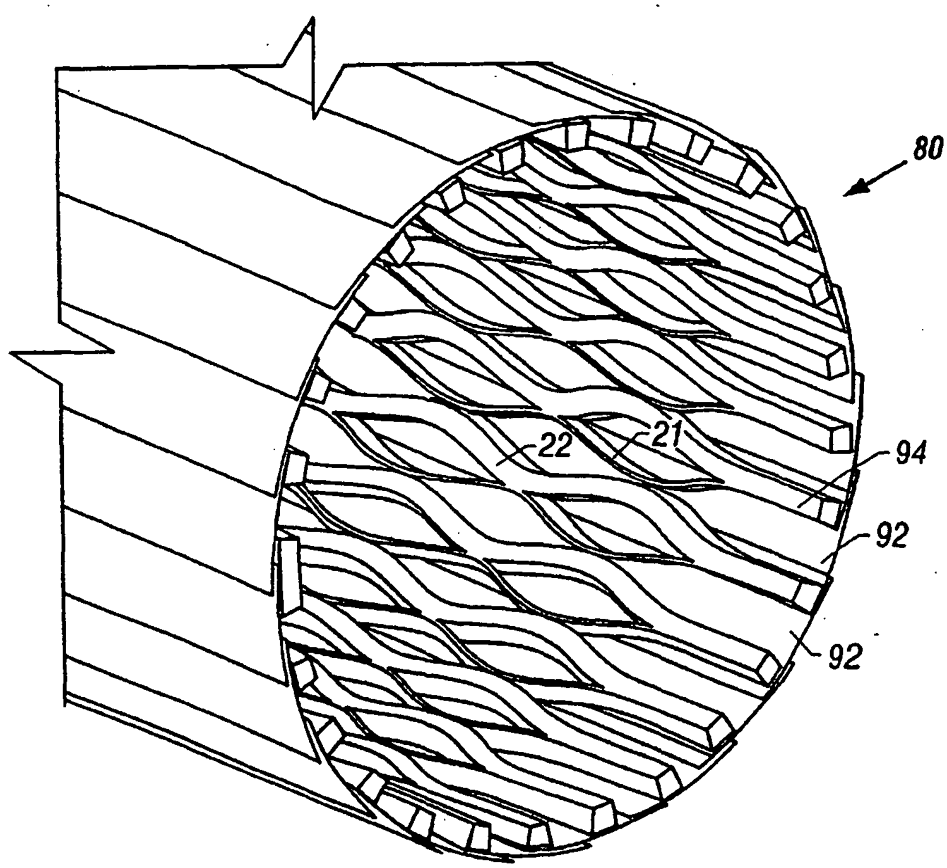


FIG. 19

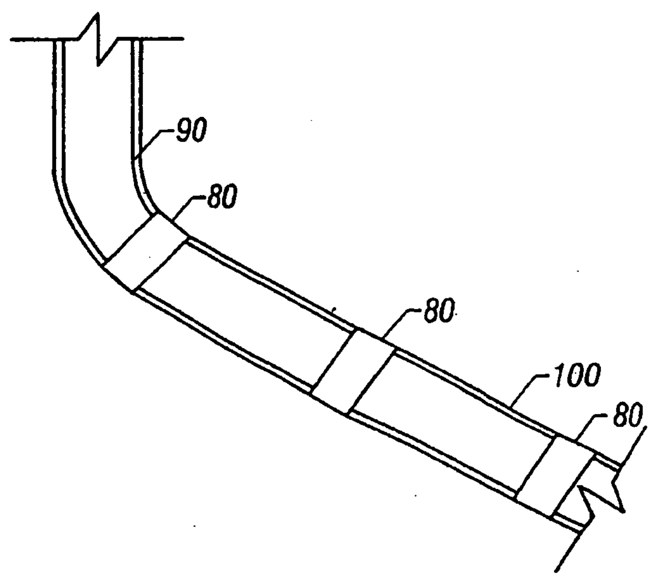


FIG. 20

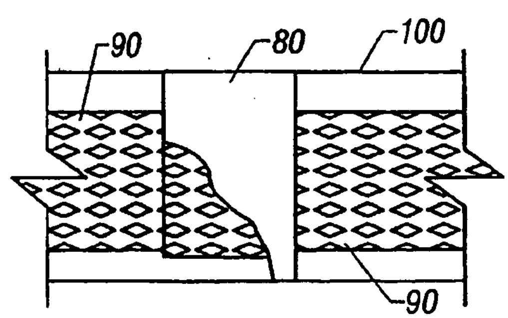


FIG. 21

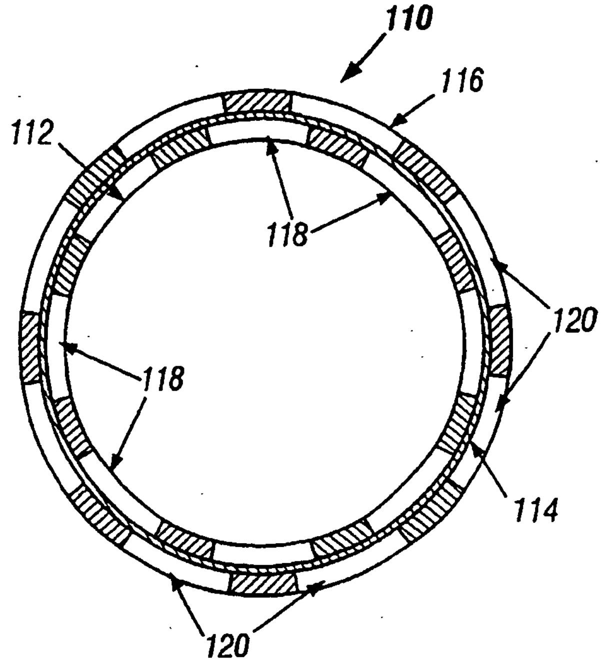


FIG. 22

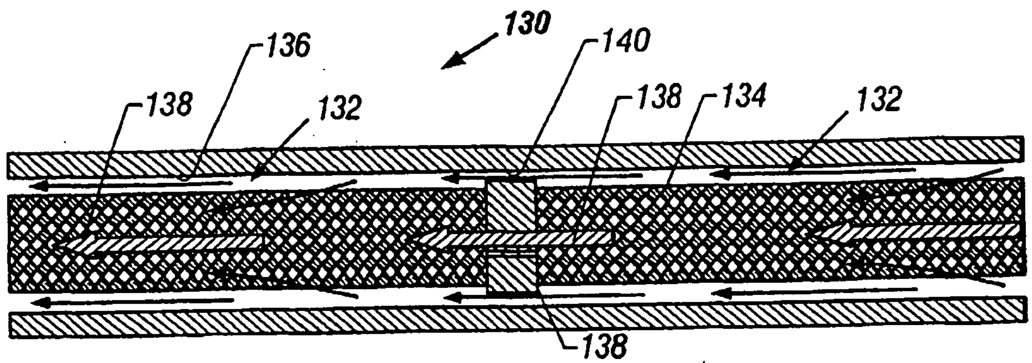


FIG. 23

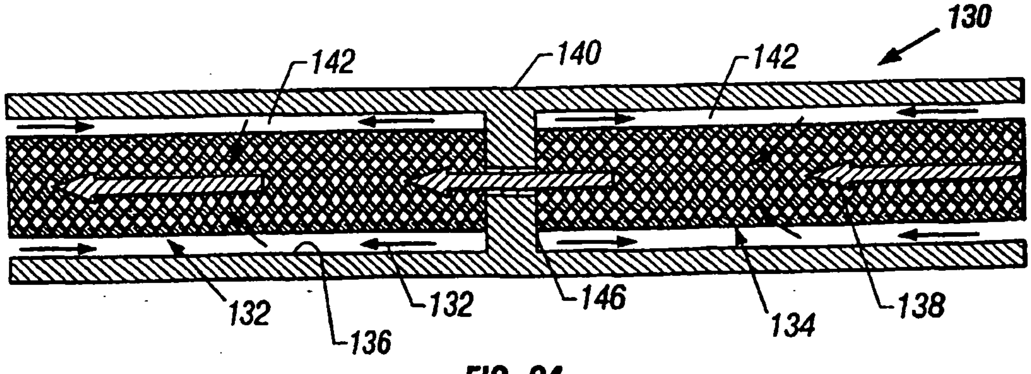


FIG. 24

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# WELLBORE ISOLATION TECHNIQUE

## FIELD OF THE INVENTION

This invention relates to equipment that can be used in the drilling and completion of boreholes in an underground formation and in the production of fluids from such wells.

## BACKGROUND OF THE INVENTION

Fluids such as oil, natural gas and water are obtained from a subterranean geologic formation (a "reservoir") by drilling a well that penetrates the fluid-bearing formation. Once the well has been drilled to a certain depth the borehole wall is supported to prevent collapse.

In many applications, it is desirable to isolate portions of the wellbore. Typically, one or more packers are deployed within the casing string and moved to a desired location within the wellbore. The packer is expanded at the desired location to form a boundary to fluid flow from one region of the wellbore to another. Often, packers are deployed with other tubulars to isolate desired regions of the annulus formed around the tubular.

It would be desirable to have a simple, functional wellbore isolation device able to function as a packer and/or a variety of other types of isolation devices.

## SUMMARY OF THE INVENTION

In one aspect of the present invention, a technique is provided for isolating regions of a wellbore from unwanted fluid flow. The technique utilizes an expandable member that may be deployed at a desired location in a wellbore and then expanded outwardly. According to one aspect of the invention, the expandable device is utilized as a packer.

## BRIEF DESCRIPTION OF THE DRAWINGS

The invention will hereafter be described with reference to the accompanying drawings, wherein like reference numerals denote like elements, and:

Figures 1A and 1B are illustrations of the forces imposed to make a bistable structure;

Figure 2A and 2B show force-deflection curves of two bistable structures;

Figures 3A - 3F illustrate expanded and collapsed states of three bistable cells with various thickness ratios;

Figures 4A and 4B illustrate a bistable expandable tubular in its expanded and collapsed states;

Figures 4C and 4D illustrate a bistable expandable tubular in collapsed and expanded states within a wellbore;

Figures 5A and 5B illustrate an expandable packer type of deployment device;

Figures 6A and 6B illustrate a mechanical packer type of deployment device;

Figures 7A - 7D illustrate an expandable swage type of deployment device;

Figures 8A - 8D illustrate a piston type of deployment device;

Figures 9A and 9B illustrate a plug type of deployment device;

Figures 10A and 10B illustrate a ball type of deployment device;

Figure 11 is a schematic of a wellbore utilizing an expandable bistable tubular;

Figure 12 illustrates a motor driven radial roller deployment device;

Figure 13 illustrates a hydraulically driven radial roller deployment device;

Figure 14 is a cross sectional view of one embodiment of the packer of the present invention;

Figure 15 is a cross sectional view of another embodiment of the packer of the present invention;

Figure 16 is a side elevation view of an embodiment of the present invention in a contracted state;

Figure 17 is a side elevation view of an embodiment of the present invention in an expanded state;

Figures 18A-C are schematic views of an alternative embodiment of the present invention;

Figure 19 is a perspective view of an alternative embodiment of the present invention;

Figure 20 is a schematic view of an alternative embodiment of the present invention;

Figure 21 is a schematic view of an alternative embodiment of the present invention;

Figure 22 is a cross-sectional view of an alternative embodiment of the present invention;

Figure 23 is a cross-sectional view taken generally along the axis of a system for utilizing a wellbore isolation device according to one embodiment of the invention; and

Figure 24 is a view similar to Figure 23 but showing an expandable component in its expanded state.

While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and are herein described in detail. It should be understood, however, that the description herein of specific embodiments is not intended to limit the invention to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

## DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

Bistable devices used in the present invention can take advantage of a principle illustrated in Figures 1A and 1B. Figure 1A shows a rod 10 fixed at each end to rigid supports 12. If the rod 10 is subjected to an axial force it begins to deform as shown in Figure 1B. As the axial force is increased rod 10 ultimately reaches its Euler buckling limit and deflects to one of the two stable positions shown as 14 and 15. If the buckled rod is now clamped in the buckled position, a force at right angles to the long axis can cause the rod to move to either of the stable positions but to no other position. When the rod is

subjected to a lateral force it must move through an angle ß before deflecting to its new stable position.

Bistable systems are characterized by a force deflection curve such as those shown in Figures 2A and 2B. The externally applied force 16 causes the rod 10 of Fig. 1B to move in the direction X and reaches a maximum 18 at the onset of shifting from one stable configuration to the other. Further deflection requires less force because the system now has a negative spring rate and when the force becomes zero the deflection to the second stable position is spontaneous.

The force deflection curve for this example is symmetrical and is illustrated in Figure 2A. By introducing either a precurvature to the rod or an asymmetric cross section the force deflection curve can be made asymmetric as shown in Figure 2B. In this system the force 19 required to cause the rod to assume one stable position is greater than the force 20 required to cause the reverse deflection. The force 20 must be greater than zero for the system to have bistable characteristics.

Bistable structures, sometimes referred to as toggle devices, have been used in industry for such devices as flexible discs, over center clamps, hold-down devices and quick release systems for tension cables (such as in sailboat rigging backstays).

Instead of using the rigid supports as shown in Figures 1A and 1B, a cell can be constructed where the restraint is provided by curved struts connected at each end as shown in Figures 3A - 3F. If both struts 21 and 22 have the same

thickness as shown in Figures 3A and 3B, the force deflection curve is linear and the cell lengthens when compressed from its open position Figure 3B to its closed position Figure 3A. If the cell struts have different thicknesses, as shown in Figures 3C - 3F, the cell has the force deflection characteristics shown in Figure 2B, and does not change in length when it moves between its two stable positions. An expandable bistable tubular can thus be designed so that as the radial dimension expands, the axial length remains constant. In one example, if the thickness ratio is over approximately 2:1, the heavier strut resists longitudinal changes. By changing the ratio of thick-to-thin strut dimensions, the opening and closing forces can be changed. For example, Figures 3C and 3D illustrated a thickness ratio of approximately 3:1, and Figures 3E and 3F illustrate a thickness ratio of approximately 6:1.

An expandable bore bistable tubular, such as casing, a tube, a patch, or pipe, can be constructed with a series of circumferential bistable connected cells 23 as shown in Figures 4A and 4B, where each thin strut 21 is connected to a thick strut 22. The longitudinal flexibility of such a tubular can be modified by changing the length of the cells and by connecting each row of cells with a compliant link. Further, the force deflection characteristics and the longitudinal flexibility can also be altered by the design of the cell shape. Figure 4A illustrates an expandable bistable tubular 24 in its expanded configuration while Figure 4B illustrates the expandable bistable tubular 24 in its contracted or collapsed configuration. Within this application the term "collapsed" is used to identify the configuration of the bistable element or device in the stable state with the smallest diameter, it is not

meant to imply that the element or device is damaged in any way. In the collapsed state, bistable tubular 24 is readily introduced into a wellbore 29, as illustrated in Figure 4C. Upon placement of the bistable tubular 24 at a desired wellbore location, it is expanded, as illustrated in Figure 4D.

The geometry of the bistable cells is such that the tubular cross-section can be expanded in the radial direction to increase the overall diameter of the tubular. As the tubular expands radially, the bistable cells deform elastically until a specific geometry is reached. At this point the bistable cells move, e.g. snap, to a final expanded geometry. With some materials and/or bistable cell designs, enough energy can be released in the elastic deformation of the cell (as each bistable cell snaps past the specific geometry) that the expanding cells are able to initiate the expansion of adjoining bistable cells past the critical bistable cell geometry. Depending on the deflection curves, a portion or even an entire length of bistable expandable tubular can be expanded from a single point.

In like manner if radial compressive forces are exerted on an expanded bistable tubular, it contracts radially and the bistable cells deform elastically until a critical geometry is reached. At this point the bistable cells snap to a final collapsed structure. In this way the expansion of the bistable tubular is reversible and repeatable. Therefore the bistable tubular can be a reusable tool that is selectively changed between the expanded state as shown in Figure 4A and the collapsed state as shown in Figure 4B.

In the collapsed state, as in Figure 4B, the bistable expandable tubular is easily inserted into the wellbore and placed into position. A deployment device is then used to change the configuration from the collapsed state to the expanded state.

In the expanded state, as in Figure 4A, design control of the elastic material properties of each bistable cell can be such that a constant radial force can be applied by the tubular wall to the constraining wellbore surface. The material properties and the geometric shape of the bistable cells can be designed to give certain desired results.

One example of designing for certain desired results is an expandable bistable tubular string with more than one diameter throughout the length of the string. This can be useful in boreholes with varying diameters, whether designed that way or as a result of unplanned occurrences such as formation washouts or keyseats within the borehole. This also can be beneficial when it is desired to have a portion of the bistable expandable device located inside a cased section of the well while another portion is located in an uncased section of the well. Figure 11 illustrates one example of this condition. A wellbore 40 is drilled from the surface 42 and comprises a cased section 44 and an openhole section 46. An expandable bistable device 48 having segments 50, 52 with various diameters is placed in the well. The segment with a larger diameter 50 is used to stabilize the openhole section 46 of the well, while the segment having a reduced diameter 52 is located inside the cased section 44 of the well.

Bistable collars or connectors 24A (see Figure 4C) can be designed to allow sections of the bistable expandable tubular to be joined together into a string of useful lengths using the same principle as illustrated in Figure 4A and 4B. This bistable connector 24A also incorporates a bistable cell design that allows it to expand radially using the same mechanism as for the bistable expandable tubular component. Exemplary bistable connectors have a diameter slightly larger than the expandable tubular sections that are being joined. The bistable connector is then placed over the ends of the two sections and mechanically attached to the expandable tubular sections. Mechanical fasteners such as screws, rivets or bands can be used to connect the connector to the tubular sections. The bistable connector typically is designed to have an expansion rate that is compatible with the expandable tubular sections, so that it continues to connect the two sections after the expansion of the two segments and the connector.

Alternatively, the bistable connector can have a diameter smaller than the two expandable tubular sections joined. Then, the connector is inserted inside of the ends of the tubulars and mechanically fastened as discussed above. Another embodiment would involve the machining of the ends of the tubular sections on either their inner or outer surfaces to form an annular recess in which the connector is located. A connector designed to fit into the recess is placed in the recess. The connector would then be mechanically attached to the ends as described above. In this way the connector forms a relatively flush-type connection with the tubular sections.

A conveyance device 31 transports the bistable expandable tubular lengths and bistable connectors into the wellbore and to the correct position. (See Figures 4C and 4D). The conveyance device may utilize one or more mechanisms such as wireline cable, coiled tubing, coiled tubing with wireline conductor, drill pipe, tubing or casing.

A deployment device 33 can be incorporated into the overall assembly to expand the bistable expandable tubular and connectors. (See Figures 4C and 4D). Deployment devices can be of numerous types such as an inflatable packer element, a mechanical packer element, an expandable swage, a piston apparatus, a mechanical actuator, an electrical solenoid, a plug type apparatus, e.g. a conically shaped device pulled or pushed through the tubing, a ball type apparatus or a rotary type expander as further discussed below.

An inflatable packer element is shown in Figures 5A and 5B and is a device with an inflatable bladder, element, or bellows incorporated into the bistable expandable tubular system bottom hole assembly. In the illustration of Figure 5A, the inflatable packer element 25 is located inside the entire length, or a portion, of the initial collapsed state bistable tubular 24 and any bistable expandable connectors (not shown). Once the bistable expandable tubular system is at the correct deployment depth, the inflatable packer element 25 is expanded radially by pumping fluid into the device as shown in Figure 5B. The inflation fluid can be pumped from the surface through tubing or drill pipe, a mechanical pump, or via a downhole electrical pump which is powered via wireline cable. As the inflatable packer element 25 expands, it forces the bistable expandable tubular 24

to also expand radially. At a certain expansion diameter, the inflatable packer element causes the bistable cells in the tubular to reach a critical geometry where the bistable "snap" effect is initiated, and the bistable expandable tubular system expands to its final diameter. Finally the inflatable packer element 25 is deflated and removed from the deployed bistable expandable tubular 24.

A mechanical packer element is shown in Figures 6A and 6B and is a device with a deformable plastic element 26 that expands radially when compressed in the axial direction. The force to compress the element can be provided through a compression mechanism 27, such as a screw mechanism, cam, or a hydraulic piston. The mechanical packer element deploys the bistable expandable tubulars and connectors in the same way as the inflatable packer element. The deformable plastic element 26 applies an outward radial force to the inner circumference of the bistable expandable tubulars and connectors, allowing them in turn to expand from a contracted position (see Figure 6A) to a final deployment diameter (see Figure 6B).

An expandable swage is shown in Figures 7A - 7D and comprises a series of fingers 28 that are arranged radially around a conical mandrel 30. Figures 7A and 7C show side and top views respectively. When the mandrel 30 is pushed or pulled through the fingers 28 they expand radially outwards, as illustrated in Figures 7B and 7D. An expandable swage is used in the same manner as a mechanical packer element to deploy a bistable expandable tubular and connector.

A piston type apparatus is shown in Figures 8A - 8D and

comprises a series of pistons 32 facing radially outwardly and used as a mechanism to expand the bistable expandable tubulars and connectors. When energized, the pistons 32 apply a radially directed force to deploy the bistable expandable tubular assembly as per the inflatable packer element. Figures 8A and 8C illustrate the pistons retracted while Figures 8B and 8D show the pistons extended. The piston type apparatus can be actuated hydraulically, mechanically or electrically.

A plug type actuator is illustrated in Figures 9A and 9B and comprises a plug 34 that is pushed or pulled through the bistable expandable tubulars 24 or connectors as shown in Figure 9A. The plug is sized to expand the bistable cells past their critical point where they will snap to a final expanded diameter as shown in Figure 9B.

A ball type actuator is shown in Figures 10A and 10B and operates when an oversized ball 36 is pumped through the middle of the bistable expandable tubulars 24 and connectors. To prevent fluid losses through the cell slots, an expandable elastomer based liner 38 is run inside the bistable expandable tubular system. The liner 38 acts as a seal and allows the ball 36 to be hydraulically pumped through the bistable tubular 24 and connectors. The effect of pumping the ball 36 through the bistable expandable tubulars 24 and connectors is to expand the cell geometry beyond the critical bistable point, allowing full expansion to take place as shown in Figure 10B. Once the bistable expandable tubulars and connectors are expanded, the elastomer sleeve 38 and ball 36 are withdrawn.

Radial roller type actuators also can be used to expand the

bistable tubular sections. Figure 12 illustrates a motor driven expandable radial roller tool. The tool comprises one or more sets of arms 58 that are expanded to a set diameter by means of a mechanism and pivot. On the end of each set of arms is a roller 60. Centralizers 62 can be attached to the tool to locate it correctly inside the wellbore and the bistable tubular 24. A motor 64 provides the force to rotate the whole assembly, thus turning the roller(s) circumferentially inside the wellbore. The axis of the roller(s) is such as to allow the roller(s) to rotate freely when brought into contact with the inner surface of the tubular. Each roller can be conically-shaped in section to increase the contact area of roller surface to the inner wall of the tubular. The rollers are initially retracted and the tool is run inside the collapsed bistable tubular. The tool is then rotated by the motor 64, and rollers 60 are moved outwardly to contact the inner surface of the bistable tubular. Once in contact with the tubular, the rollers are pivoted outwardly a greater distance to apply an outwardly radial force to the bistable tubular. The outward movement of the rollers can be accomplished via centrifugal force or an appropriate actuator mechanism coupled between the motor 64 and the rollers 60.

The final pivot position is adjusted to a point where the bistable tubular can be expanded to the final diameter. The tool is then longitudinally moved through the collapsed bistable tubular, while the motor continues to rotate the pivot arms and rollers. The rollers follow a shallow helical path 66 inside the bistable tubular, expanding the bistable cells in their path. Once the bistable tubular is deployed, the tool rotation is stopped and the roller retracted. The tool is then withdrawn

from the bistable tubular by a conveyance device 68 that also can be used to insert the tool.

Figure 13 illustrates a hydraulically driven radial roller deployment device. The tool comprises one or more rollers 60 that are brought into contact with the inner surface of the bistable tubular by means of a hydraulic piston 70. The outward radial force applied by the rollers can be increased to a point where the bistable tubular expands to its final diameter. Centralizers 62 can be attached to the tool to locate it correctly inside the wellbore and bistable tubular 24. The rollers 60 are initially retracted and the tool is run into the collapsed bistable tubular 24. The rollers 60 are then deployed and push against the inside wall of the bistable tubular 24 to expand a portion of the tubular to its final diameter. The entire tool is then pushed or pulled longitudinally through the bistable tubular 24 expanding the entire length of bistable cells 23. Once the bistable tubular 24 is deployed in its expanded state, the rollers 60 are retracted and the tool is withdrawn from the wellbore by the conveyance device 68 used to insert it. By altering the axis of the rollers 60, the tool can be rotated via a motor as it travels longitudinally through the bistable tubular 24.

Power to operate the deployment device can be drawn from one or a combination of sources such as: electrical power supplied either from the surface or stored in a battery arrangement along with the deployment device, hydraulic power provided by surface or downhole pumps, turbines or a fluid accumulator, and mechanical power supplied through an

appropriate linkage actuated by movement applied at the surface or stored downhole such as in a spring mechanism.

The bistable expandable tubular system is designed so the internal diameter of the deployed tubular is expanded to maintain a maximum cross-sectional area along the expandable tubular. This feature enables mono-bore wells to be constructed and facilitates elimination of problems associated with traditional wellbore casing systems where the casing outside diameter must be stepped down many times, restricting access, in long wellbores.

The bistable expandable tubular system can be applied in numerous applications such as an expandable open hole liner where the bistable expandable tubular 24 is used to support an open hole formation by exerting an external radial force on the wellbore surface. As bistable tubular 24 is radially expanded, the tubular moves into contact with the surface forming wellbore 29. These radial forces help stabilize the formations and allow the drilling of wells with fewer conventional casing strings. The open hole liner also can comprise a material, e.g. a wrapping, that reduces the rate of fluid loss from the wellbore into the formations. The wrapping can be made from a variety of materials including expandable metallic and/or elastomeric materials. By reducing fluid loss into the formations, the expense of drilling fluids can be reduced and the risk of losing circulation and/or borehole collapse can be minimized.

Liners also can be used within wellbore tubulars for purposes such as corrosion protection. One example of a corrosive environment is the environment that results when

carbon dioxide is used to enhance oil recovery from a producing formation. Carbon dioxide ($CO_2$) readily reacts with any water ($H_2O$) that is present to form carbonic acid ($H_2CO_3$). Other acids can also be generated, especially if sulfur compounds are present. Tubulars used to inject the carbon dioxide as well as those used in producing wells are subject to greatly elevated corrosion rates. The present invention can be used to place protective liners, e.g. a bistable tubular 24, within an existing tubular to minimize the corrosive effects and to extend the useful life of the wellbore tubulars.

Another exemplary application involves use of the bistable tubular 24 as an expandable perforated liner. The open bistable cells in the bistable expandable tubular allow unrestricted flow from the formation while providing a structure to stabilize the borehole.

Still another application of the bistable tubular 24 is as an expandable sand screen where the bistable cells are sized to act as a sand control screen. Also, a filter material can be combined with the bistable tubular as explained below. For example, an expandable screen element can be affixed to the bistable expandable tubular. The expandable screen element can be formed as a wrapping around bistable tubular 24. It has been found that the imposition of hoop stress forces onto the wall of a borehole will in itself help stabilize the formation and reduce or eliminate the influx of sand from the producing zones, even if no additional screen element is used.

The above described bistable expandable tubulars can be made in a variety of manners such as: cutting appropriately

shaped paths through the wall of a tubular pipe thereby creating an expandable bistable device in its collapsed state; cutting patterns into a tubular pipe thereby creating an expandable bistable device in its expanded state and then compressing the device into its collapsed state; cutting appropriate paths through a sheet of material, rolling the material into a tubular shape and joining the ends to form an expandable bistable device in its collapsed state; or cutting patterns into a sheet of material, rolling the material into a tubular shape, joining the adjoining ends to form an expandable bistable device in its expanded state and then compressing the device into its collapsed state.

The materials of construction for the bistable expandable tubulars can include those typically used within the oil and gas industry such as carbon steel. They can also be made of specialty alloys (such as a monel, inconel, hastelloy or tungsten-based alloys) if the application requires.

The configurations shown for the bistable tubular 24 are illustrative of the operation of a basic bistable cell. Other configurations may be suitable, but the concept presented is also valid for these other geometries.

In Figures 14 and 15, a packer 80 formed of bistable cells is illustrated. The packer 80 has a tubular 82 formed of bistable cells 83, such as those previously discussed. In addition, the packer 80 has at least one seal 84 along at least a portion of its length. An exemplary seal 84 may include one or more layers positioned internally, externally, or both with

respect to tubular 82. Additionally, the layer(s) may be intermixed with the openings formed in the cells.

Figure 14 illustrates an embodiment having an internal and an external seal 84. Figure 15 illustrates a packer 80 having only an internal seal 84. The seal 84 may be formed of an elastomer or other material. Further, the properties of the seal 84 allow it to at least match the expansion ratio of the tubular 82. Folds or other design characteristics of the seal 84 may be used to facilitate the expansion.

Also, a resin or catalyst 85 may be used to allow the seal 84 to harden after setting. In one alternative embodiment a resin or other flowable material is placed between the layers of seals 84 (as in Figure 14). Once the packer 80 is placed in the well and expanded, the flowable material may be hardened or otherwise altered to improve the sealing characteristics of the packer 80. In some applications, hardening of the resin or other material requires heating of the material by a service tool. The packer 80 can be expanded as described herein, and may comprise a variety of bistable cells. In one embodiment of use, the packer 80 is deployed on a run-in tool that includes an expanding tool. The packer 80 is positioned at the desired location and expanded to seal against the walls of the casing or other tubular. Typically, the packer 80 is connected to a tubing or other conduit that extends downhole below the packer 80. The packer 80 provides a seal in the annulus to prevent or restrict fluid flow longitudinally in the well (the typical use for packers). The present invention also may act as a well anchor which includes or excludes the seal 84.

In Figure 16, an alternative embodiment is illustrated in which the packer 80 forms a portion of a conduit. In the embodiment shown, a well conduit 90 (such as a tubing) has a portion (marked as the packer 80) that is cut to form the bistable cells. The packer portion 80 has a seal 84 thereon as previously described. In Figure 16, a portion of the seal material 84 is illustrated as removed to reveal the bistable cells 83 in the underlying tubular 82. In Figure 17, the packer portion 80 is illustrated in its expanded state. It should be noted that in typical applications the well conduit 90 which does not have bistable cells formed therein, does not expand. Thus, one embodiment for attaching the well conduit to the packer 80 is to form the packer 80 as an integral part of the well conduit 90 (note that a welded connection resembles this embodiment and is an alternative method of forming the present invention). Other methods include conventional methods of non-integral connection.

In alternative embodiments, the well conduit has a plurality of bistable cell packers 80 formed thereon. In yet another alternative embodiment, a portion or portions 91 of the well conduit in addition to the packer portions 80 are formed of bistable cells so that these other portions also undergo expansion (see Figure 17). The other portions may or may not have a material applied thereto. For example, the other portion may have a screen or filter material applied thereto to provide a well sand screen.

Referring to Figures 18A-C, an alternative design of the present invention is illustrated in a schematic, partial cross-sectional view. The expandable packer is shown in the retracted

and expanded states, respectively, and in partial side elevational view (Figure 18C). The packer shown includes a base tubular 82 formed of thin struts 21 and thick struts 22 forming bistable cells 23/83 as previously described. Slats 92 are attached to the tubing 82 at one edge and extend generally longitudinally in the embodiment shown (see Figure 18C). Specifically, each slat 92 is attached to the tubing 82 at the thick struts 22, and the width of the slats is such that they overlap at least the adjacent slat when the tubing 82 is in the expanded state. Although illustrated as having a slat attached to each of the thick struts, the packer may have a slat attached to alternate thick struts 22 or in other configurations. Furthermore, the slats may extend in a direction other than the longitudinal direction. The slats 92 slide over one another during expansion so that the outside of the tubing 82 is covered by the overlapping slats 92.

A seal 84 may be attached to the slats 92 to provide the seal for the packer. Although shown in the figures as folded, the seal 84, may have other characteristics that facilitate its ability to expand with the slats 92 and tubular 82. Also, the seal 84 may have other characteristics previously mentioned (e.g., resin, internal seal, etc).

It should be noted that although described as a packer, the present invention may be used to provide isolation over a long length as opposed to a traditional packer or downhole tool which generally seals only a relatively short longitudinal distance. Thus, the present invention may be used in a manner similar to a casing to provide isolation for an extended length.

In Figure 19, a perspective view of packer 80 (or isolation device) having a plurality of slats 92 attached thereto is illustrated in an overlapping arrangement as previously described. The tubing 82 includes end extensions 94 that extend longitudinally from the endmost cells. The slats 92 may be attached to the end extensions 94, to certain portions of the thick struts 22 and/or to certain thick struts 22. In one embodiment, for example, the struts 92 are attached to the thick struts which are longitudinally aligned with the end extensions 94. Although generally shown as attached at an edge of the slats 92, the slats also may attach to the tubing 82 at a position intermediate the edges.

In Figure 20, an expandable tubing (or conduit) 90 is illustrated positioned in a well 100. The conduit 90 includes a plurality of spaced packers 80 or expandable sealing devices. The expandable packers 80 engage the wellbore wall preventing annular flow thereby. Therefore, any microannulus formed between the expandable tubing 90 and the well 100 (which may include a casing) is sealed in the longitudinal direction to restrict or prevent unwanted flow thereby. The conduit 90 may include one or more such packers 80, as desired, to control the flow. Further, the packers 80 may be spaced at regular intervals or at some other predetermined spacing to control the flow in the annulus as needed.

In one example, illustrated schematically in Figure 21, the individual joints of tubing 90 are interconnected by a packer 80 to compartmentalize each joint of conduit from the adjacent joint(s). The packer 80 can be a separate connector as shown in Figure 21 or it can be formed as part of the joint.

Accordingly, the packer 80 can be positioned at an end of the joint 90, in the middle of the joint 90, or at any other location along its length. In one embodiment both conduit 90 and packers 80, of Figures 20 and 21, are formed of bistable cells.

Another embodiment of a downhole device is illustrated in Figure 22. In this embodiment, a downhole tool 110 is formed of an inner tube 112 surrounded by a fluid retention layer 114. An outer tube 116 is disposed to surround fluid retention layer 114.

Inner tube 112, fluid retention layer 114 and outer tube 116 are expandable. For example, inner tube 112 may comprise a plurality of bistable cells 118 to facilitate radial expansion towards the stable, expanded state. Similarly, outer tube 116 may comprise a plurality of bistable cells 120 also designed to facilitate expansion of outer tube 116 towards its stable, expanded state. The exact arrangement of bistable cells in the inner tube 112 and outer tube 116 are optimized according to different tube diameters and desired expansion characteristics. Fluid retention layer 114, on the other hand, may be made from a variety of materials that permit expansion. For example, the layer may be formed from a solid polymeric, e.g. rubber, sheet or an overlapping metallic foil able to uncoil as inner tube 112 and outer tube 116 are expanded. Such an overlapping metal foil can be formed from a plurality of individual, overlapping sheets or from a single coiled sheet.

In the embodiment illustrated, outer tube 116 is rotated slightly such that bistable cells 120 are out of phase with

bistable cells 118. In other words, bistable cells 120 at least partially overlap bistable cells 118, as illustrated in Figure 22. This arrangement creates a quasi-solid, fluid-tight structure. The structure can be used as a formation shut-off device, such as a packer, or as an expandable casing patch.

Another system for compartmentalizing portions of a wellbore is labeled as system 130 and illustrated in Figures 23 and 24. System 130 is designed to isolate an annular flow path 132 disposed between a sand screen 134, or other tubular downhole device, and a formation wall 136 defining the wellbore.

During operation of sand screen 134, fluid is drawn from formation wall 136 into the interior of sand screen 134 and produced along a main production fluid path 138. However, if uninterrupted, flow can also be created along annular flow path 132 between sand screen 134 and formation wall 136. This flow along the wellbore wall potentially leads to a variety of problems, such as sanding or formation collapse.

Accordingly, a flow isolation device 140 is mounted to sand screen 134 at one or more desired intervals. Similar to a packer, flow isolation device 140 isolates portions 142 of the annulus between sand screen 134 and formation wall 136, as best illustrated in Figure 24. This isolation blocks or at least inhibits the detrimental flow along annular flow path 132. In one embodiment, flow isolation device 140 can be disposed through sand screen 134 at joints or intervals that separate one expandable screen section from the next. In other embodiments, however, the flow isolation device 140 is placed at a variety of desired locations along sand screen 134. At any of these

locations, flow isolation device 140 can be expanded from a contracted state 144, as illustrated in Figure 23, to an expanded state 146 that creates isolated portions 142 of the annulus, as illustrated in Figure 24.

An exemplary flow isolation device 140 comprises an expandable device formed of bistable cells, as discussed above, that permit the device to be moved from contracted state 144 to expanded state 146 when an expansion device is moved through sand screen 134. If the flow isolation device 140 extends radially inwardly into flow path 138 in its contracted state 144, then the expansion mechanism can force flow isolation device 140 to its expanded state 146 without further expanding sand screen 134. Alternatively, both sand screen 134 and flow isolation device 140 can be expanded together until flow isolation device 140 is moved to its expanded state proximate formation wall 136. Flow isolation device 140 also may be formed from a variety of other materials, such as rubber jackets, designed to expand outwardly and seal the wellbore. Regardless of the specific design, blocking all or at least a substantial portion of this unwanted annular flow contributes to the function and longevity of production in a given wellbore.

The particular embodiments disclosed herein are illustrative only, as the invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular embodiments disclosed above may be altered or modified and all

such variations are considered within the scope and spirit of the invention. Accordingly, the protection sought herein is as set forth in the claims below.

## CLAIMS

1. A wellbore isolation device, comprising:

an expandable component having a wellbore isolation region, the wellbore isolation region comprising a bistable cell layer that can be expanded to limit fluid flow along a wellbore.

2. The wellbore isolation device as recited in claim 1, wherein the expandable component comprises a packer.

3. The wellbore isolation device as recited in claim 1, further comprising a sand screen, wherein the expandable component is coupled to the sand screen.

4. The wellbore isolation device as recited in claim 1, wherein the bistable cell layer comprises a plurality of bistable cells.

5. The wellbore isolation device as recited in claim 2, wherein the bistable cell layer comprises a plurality of bistable cells.

6. The wellbore isolation device as recited in claim 5, further comprising a seal disposed about the bistable cell layer.

7. The wellbore isolation device as recited in claim 1, wherein the bistable cell layer comprises an inner layer and an outer layer.

8. The wellbore isolation device as recited in claim 7, wherein the inner layer and the outer layer are tubular.

9. The wellbore isolation device as recited in claim 8, wherein the inner layer and the outer layer each comprise a plurality of bistable cells.

10. The wellbore isolation device as recited in claim 9, further comprising a fluid retention layer disposed between the inner layer and the outer layer.

11. The wellbore isolation device as recited in claim 9, wherein the bistable cells of the outer layer are out of phase with the bistable cells of the inner layer.

12. The wellbore isolation device as recited in claim 1, further comprising a plurality of overlapping slats connected to the bistable cell layer.

13. A method for isolating regions of a well, comprising:

placing a packer with a layer of bistable cells at a desired location in a wellbore; and

expanding the packer.

14. The method as recited in claim 12, further comprising deploying a seal layer around the layer of bistable cells.

15. The method as recited in claim 13, further comprising forming the bistable cells through a layer of metallic material.

16. The method as recited in claim 14, further comprising wrapping the metallic material into a generally tubular configuration.

17. A packer, comprising:

a tubular formed of a plurality of bistable cells; and

a seal member disposed along at least a portion of the tubular.

18. The packer as recited in claim 17, wherein the seal member comprises an internal seal.

19. The packer as recited in claim 17, wherein the seal member comprises an external seal.

20. The packer as recited in claim 18, wherein the seal member comprises an external seal.

21. The packer as recited in claim 17, wherein the seal member has an expansion ratio that at least matches an expansion ratio of the tubular.

22. The packer as recited in claim 17, further comprising a resin to facilitate hardening of the seal member after expansion.

23. The packer as recited in claim 17, further comprising a catalyst to facilitate hardening of the seal member after expansion.

24. The packer as recited in claim 17, wherein the seal member comprises a plurality of layers.

25. The packer as recited in claim 17, wherein the tubular forms a portion of a well conduit.

26. The packer as recited in claim 25, wherein the well conduit comprises at least one additional region of bistable cells.

27. The packer as recited in claim 17, further comprising a plurality of overlapping slats mounted to the tubular.

28. The packer as recited in claim 27, further comprising a seal mounted to the slats.

29. A system for isolating a portion of a wellbore, comprising:

means for forming an isolation device with a plurality of bistable cells; and

means for expanding the plurality of bistable cells within a wellbore.

30. A system for forming at least a partial seal along a wellbore, comprising:

a conduit patch having an expandable tubular component comprising a bistable cell.

31. The system as recited in claim 30, further comprising a seal coupled to the expandable tubular component.

32. The system as recited in claim 30, wherein the bistable cell comprises a plurality of bistable cells.

33. The system as recited in claim 31, wherein the bistable cell is a plurality of bistable cells.

34. The system as recited in claim 32, further comprising a resin to facilitate hardening of the seal after expansion of the expandable tubular component.

35. The system as recited in claim 32, further comprising a catalyst to facilitate hardening of the seal after expansion of the expandable tubular component.

36. A system for facilitating a desired fluid flow within a wellbore, comprising:

a tubular having a plurality of separate portions formed of bistable cells.

37. The system as recited in claim 36, wherein at least one portion of the plurality of separate portions comprises a packer.

38. The system as recited in claim 37, wherein the packer comprises a seal member.

39. The system as recited in claim 38, wherein the seal member is external to the tubular.

40. The system as recited in claim 38, wherein the seal member is internal to the tubular.

41. The system as recited in claim 36, wherein at least two portions of the plurality of separate portions comprise packers.

42. The system as recited in claim 37, wherein at least one portion of the plurality of separate portions comprises a sand screen.

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## Patents Act 1977
## Search Report under Section 17

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): E1F FJF, FLA, FKA, FKF,

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| Category | Identity of document and relevant passage | Relevant to claims |
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| A | WO 99/02818 A1 (Petroline) | - |
| A | US 5667011 (Shell) | - |

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(54) Abstract Title
**A method for well completion using an expandable isolation system**

(57) A well completion method for isolating at least one zone which comprises running into the wellbore a string with isolators 24, 26 in conjunction with a screen 28 which allows flow from the surrounding formation into the string and expanding the isolators and the screen in the wellbore. The isolators are tubular with a sleeve of an elastomeric sealing material. The screen is made of a weave in one or more layers. The completion assembly includes an inflatable expansion assembly which provides a limited expansion force and/or diameter. A plurality of zones can be isolated on a single trip.

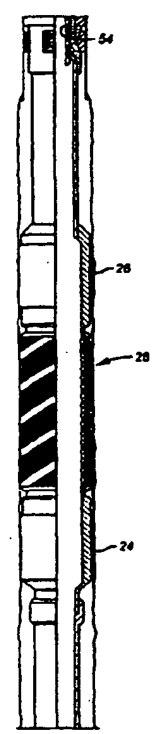


FIG. 5b

GB 2 370 301 A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

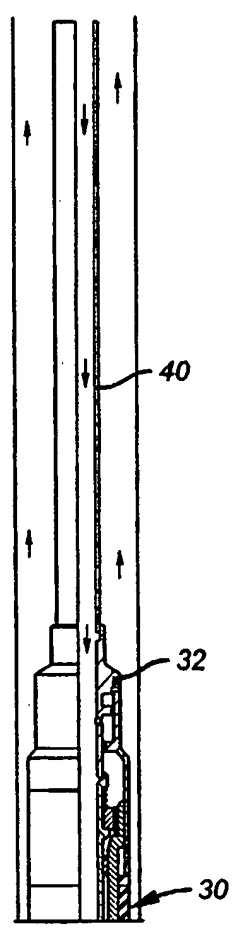


FIG. 1a

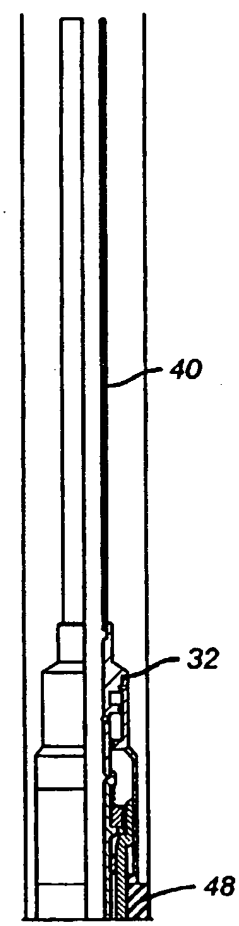


FIG. 2a

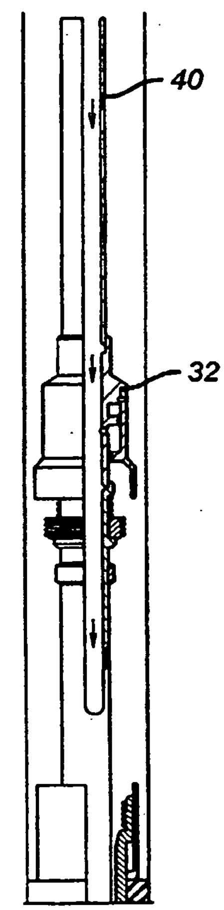


FIG. 3a

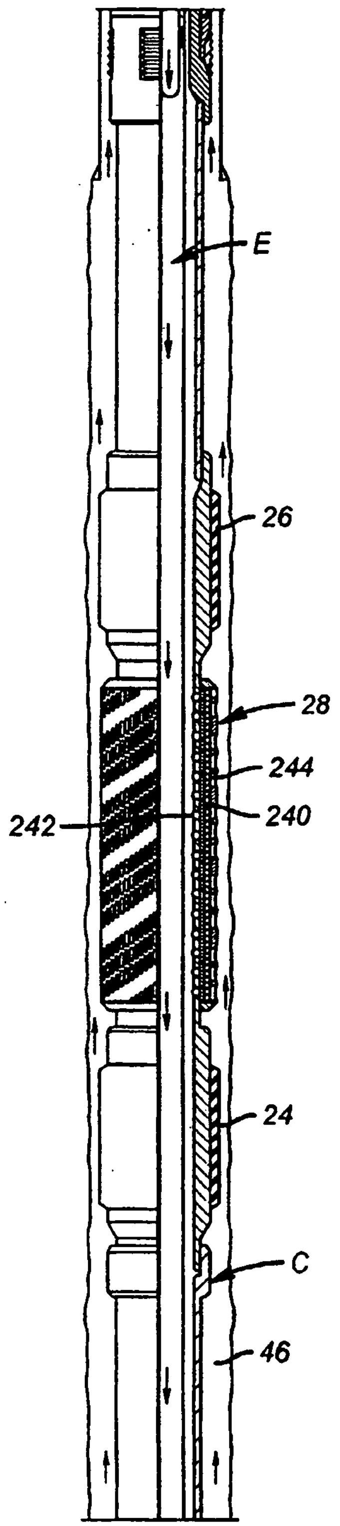


FIG. 1b

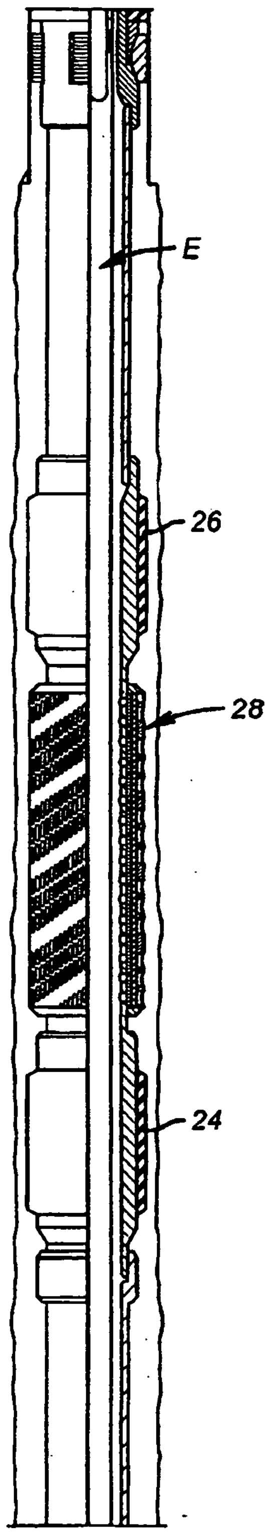


FIG. 2b

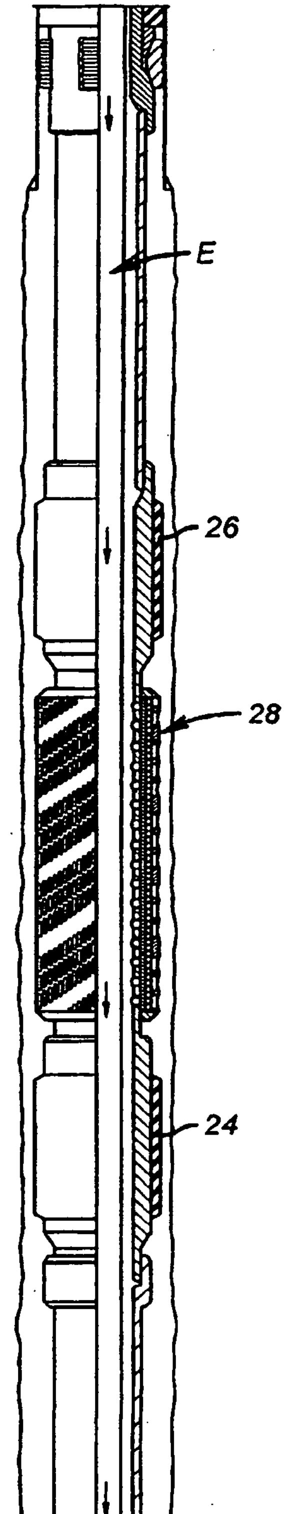


FIG. 3b

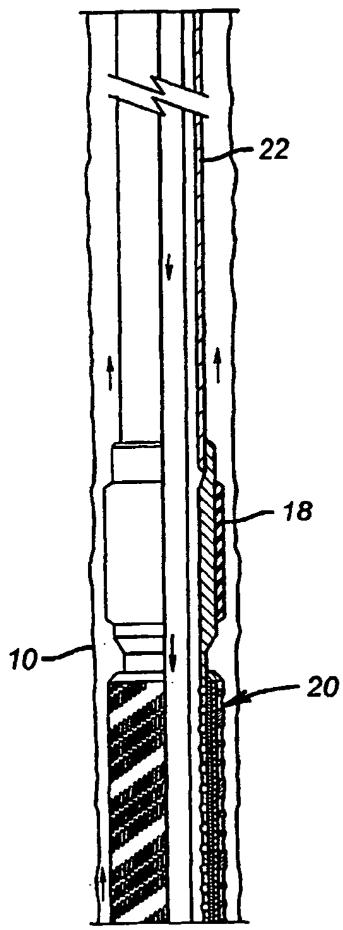


FIG. 1c

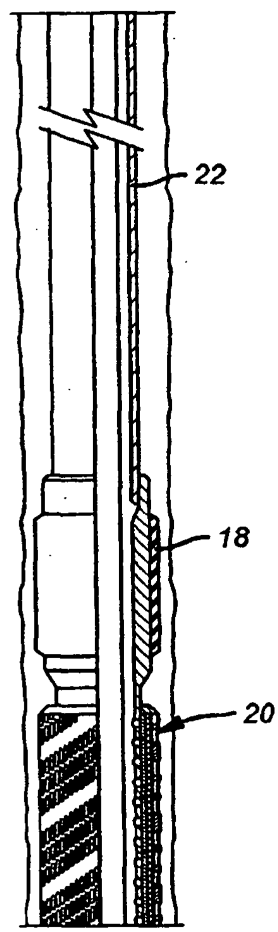


FIG. 2c

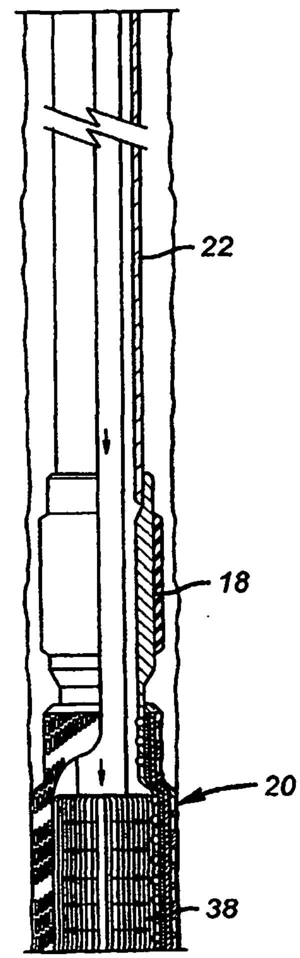


FIG. 3c

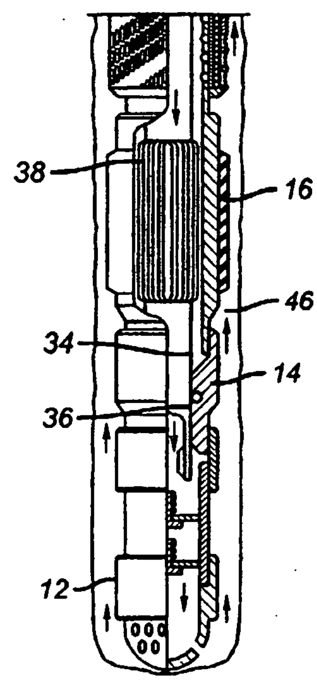


FIG. 1d

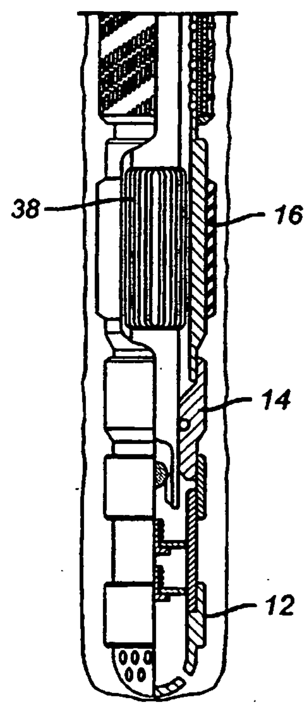


FIG. 2d

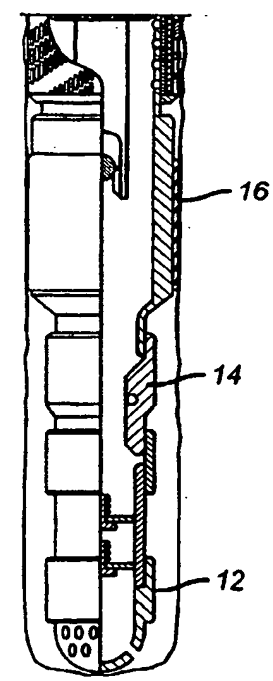


FIG. 3d

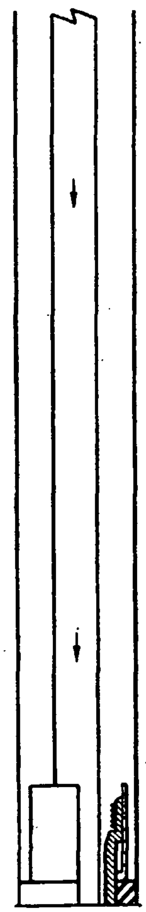

FIG. 4a

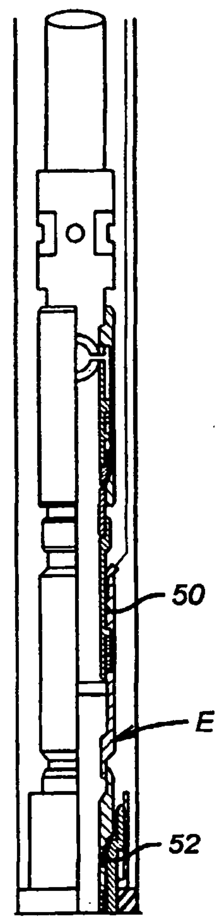


FIG. 5a

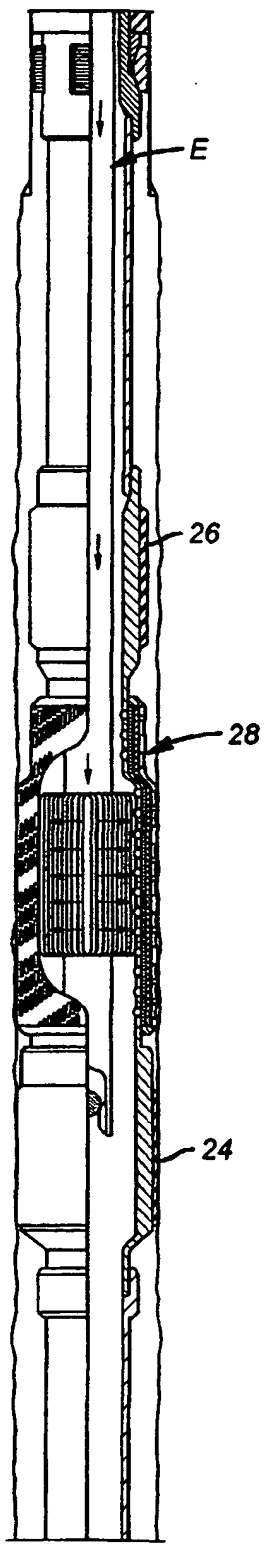


FIG. 4b

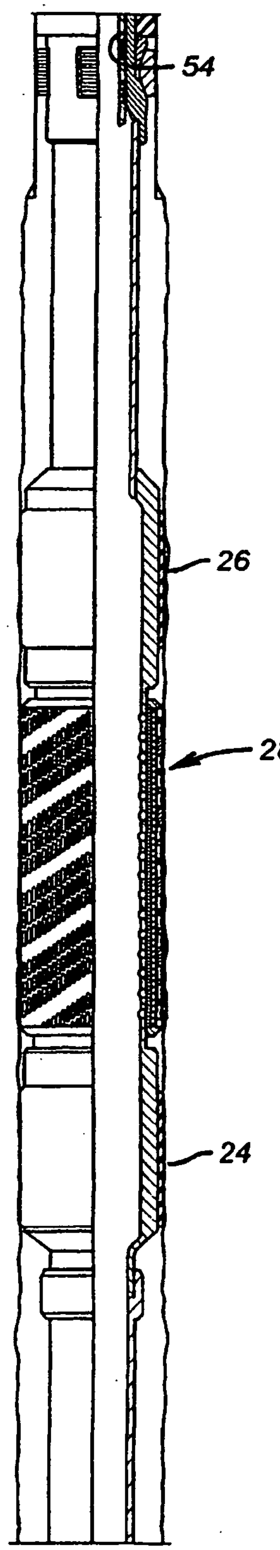


FIG. 5b

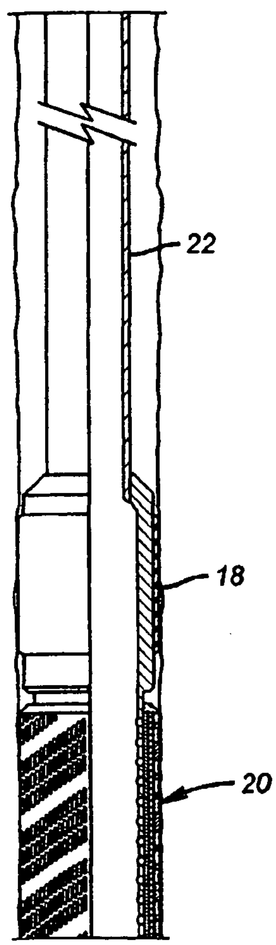


FIG. 4c

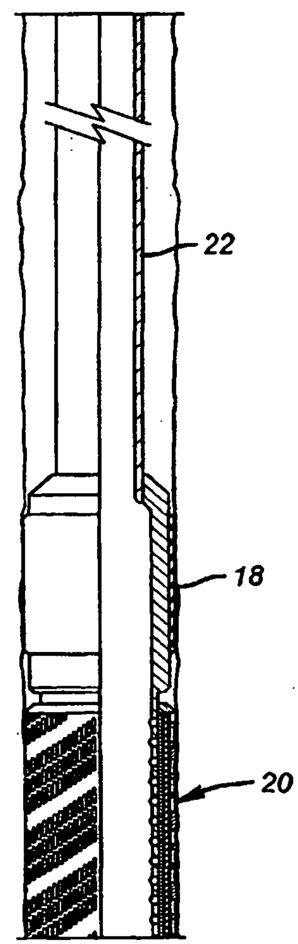


FIG. 5c

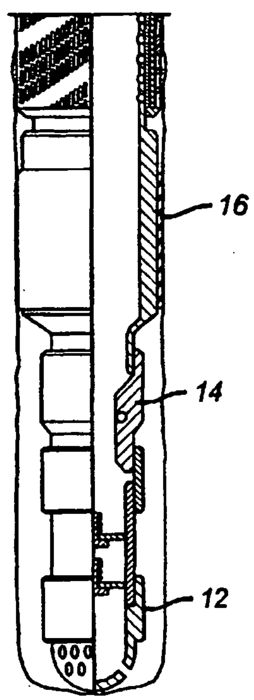


FIG. 4d

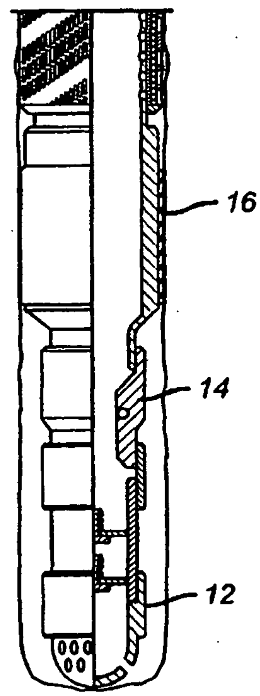


FIG. 5d

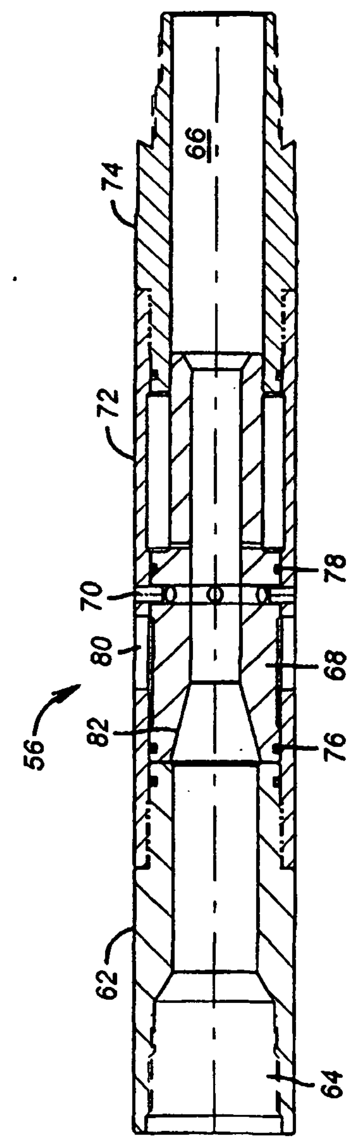
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FIG. 6

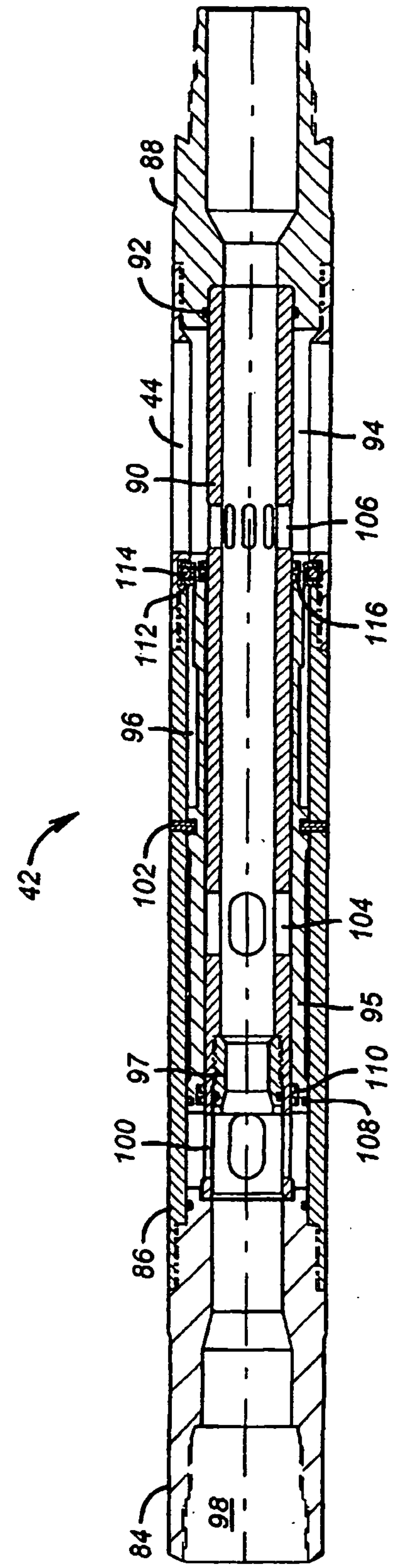
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FIG. 7

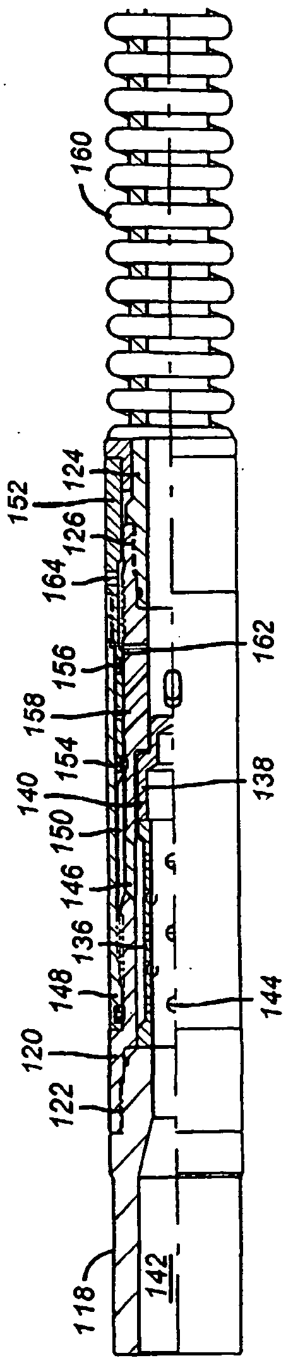
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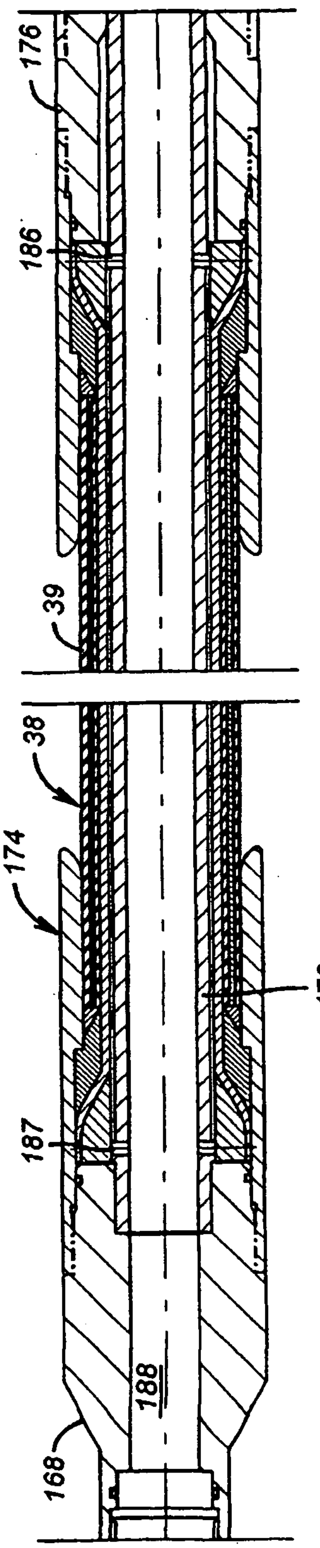
FIG. 8a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168

FIG. 9a

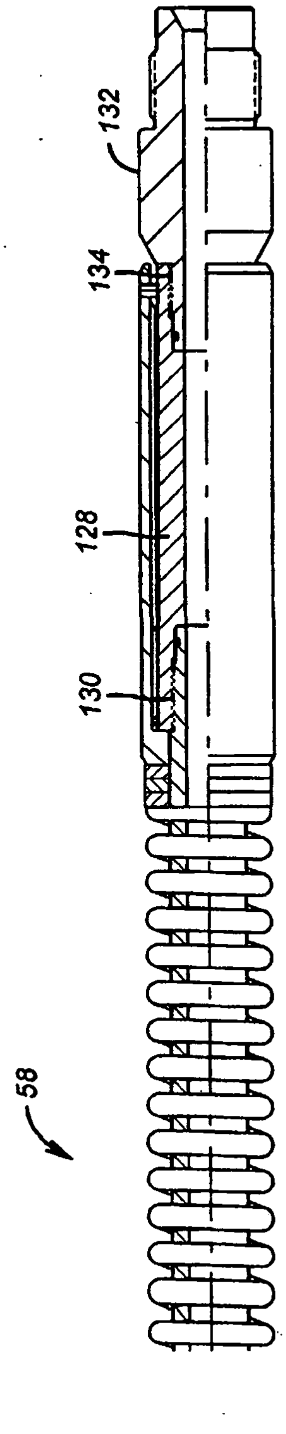


FIG. 8b

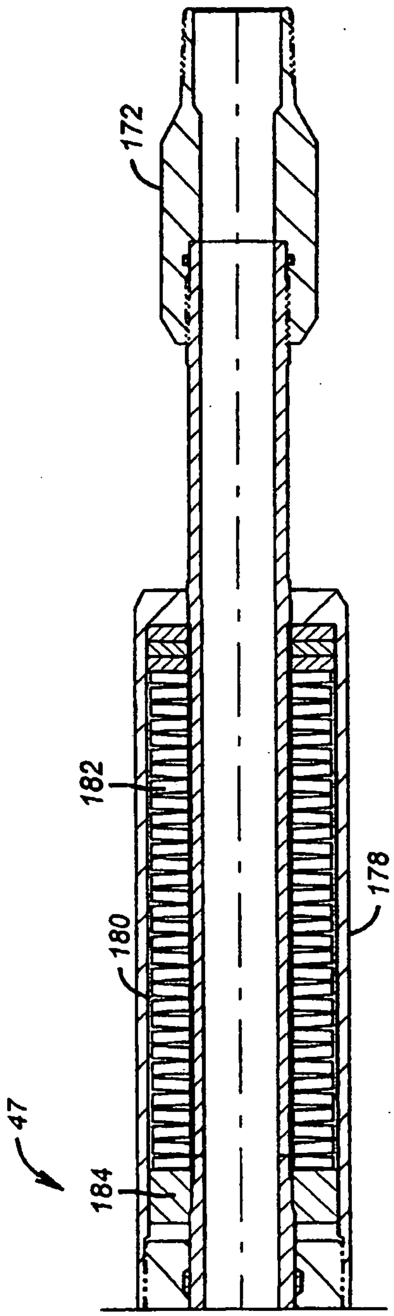


FIG. 9b

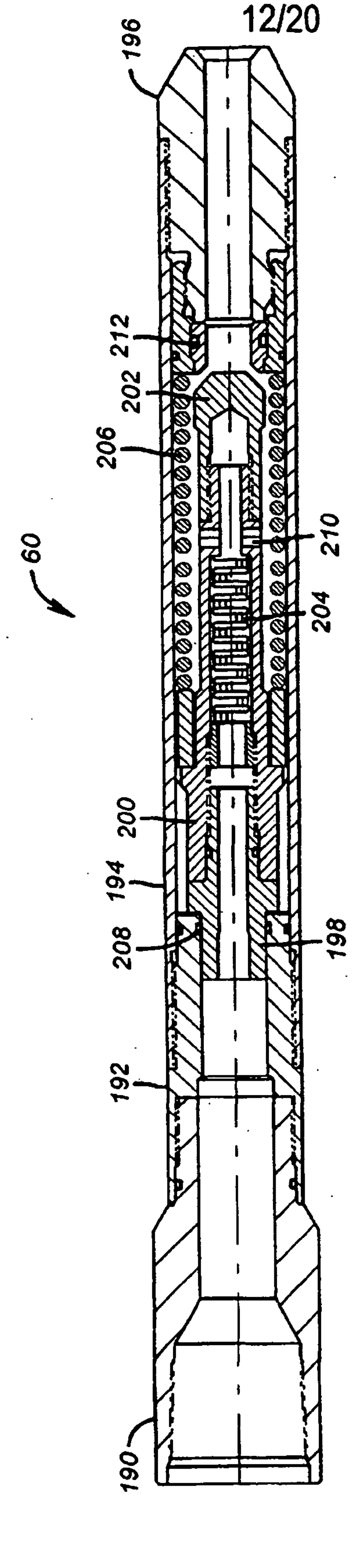


FIG. 10

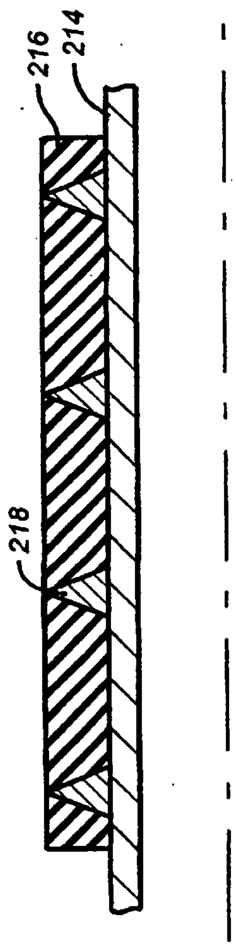


FIG. 11

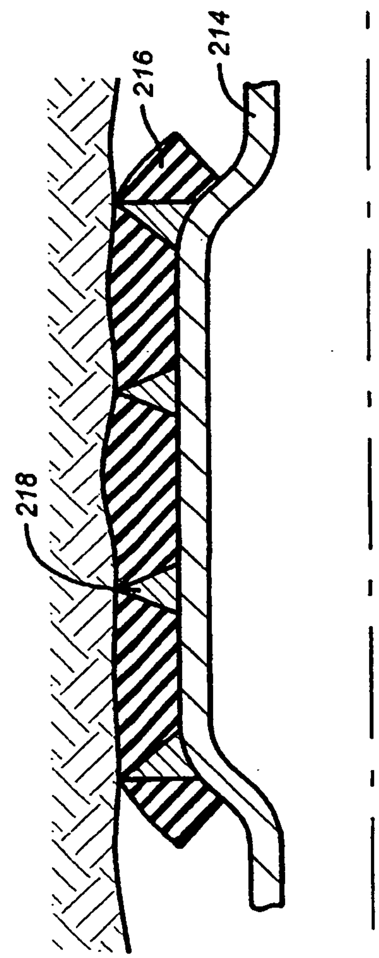


FIG. 12

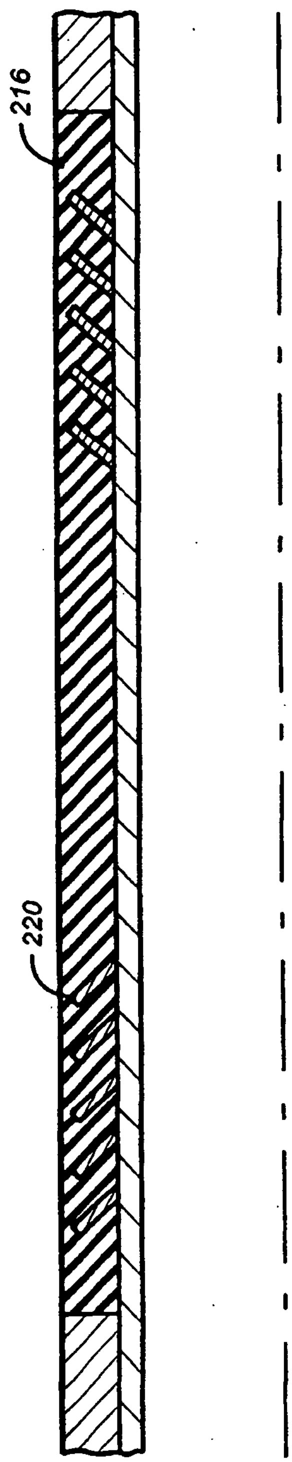


FIG. 13

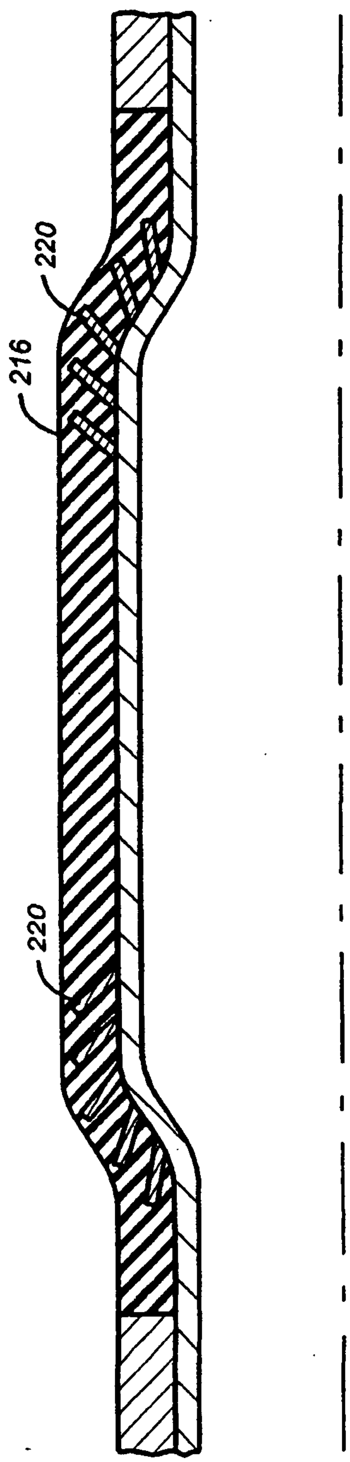


FIG. 14

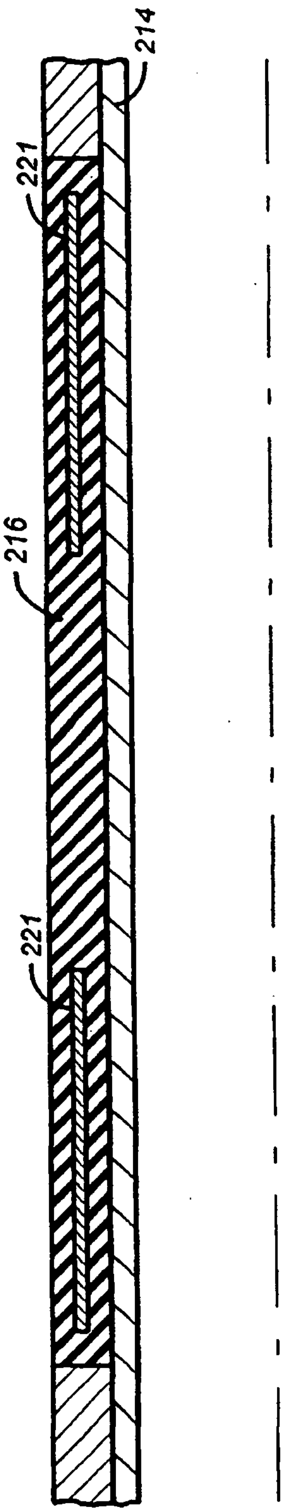


FIG. 15

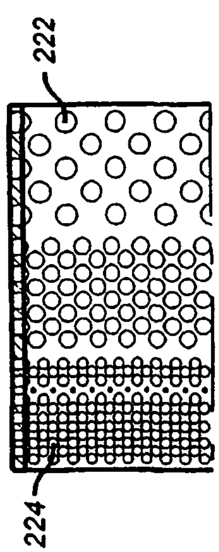


FIG. 16

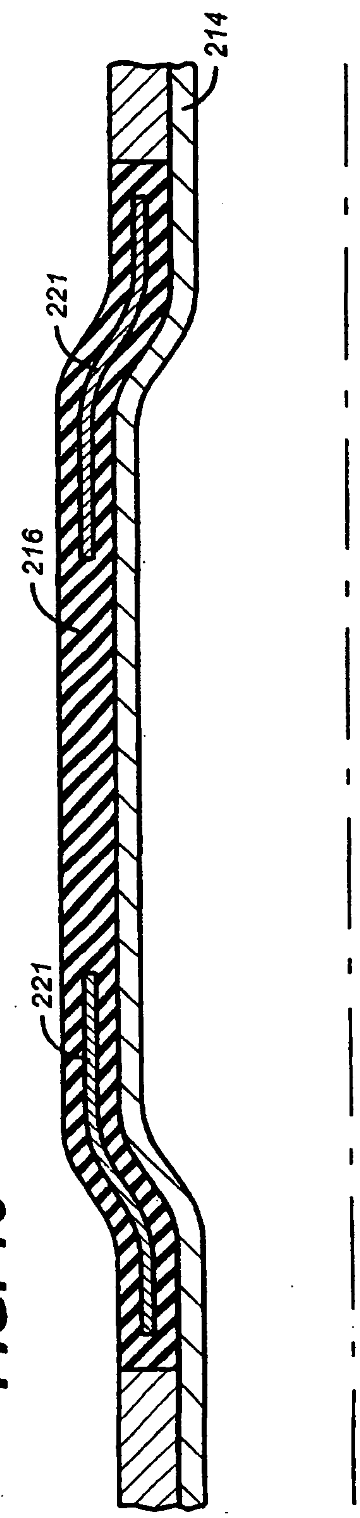


FIG. 17

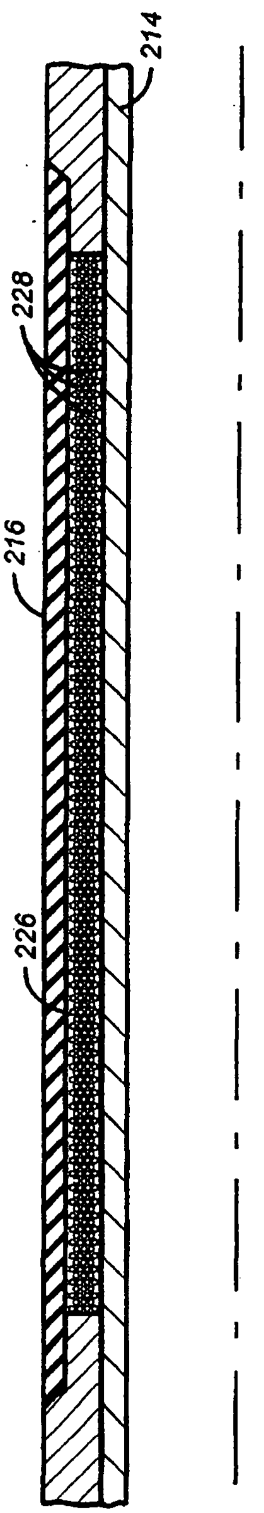


FIG. 18

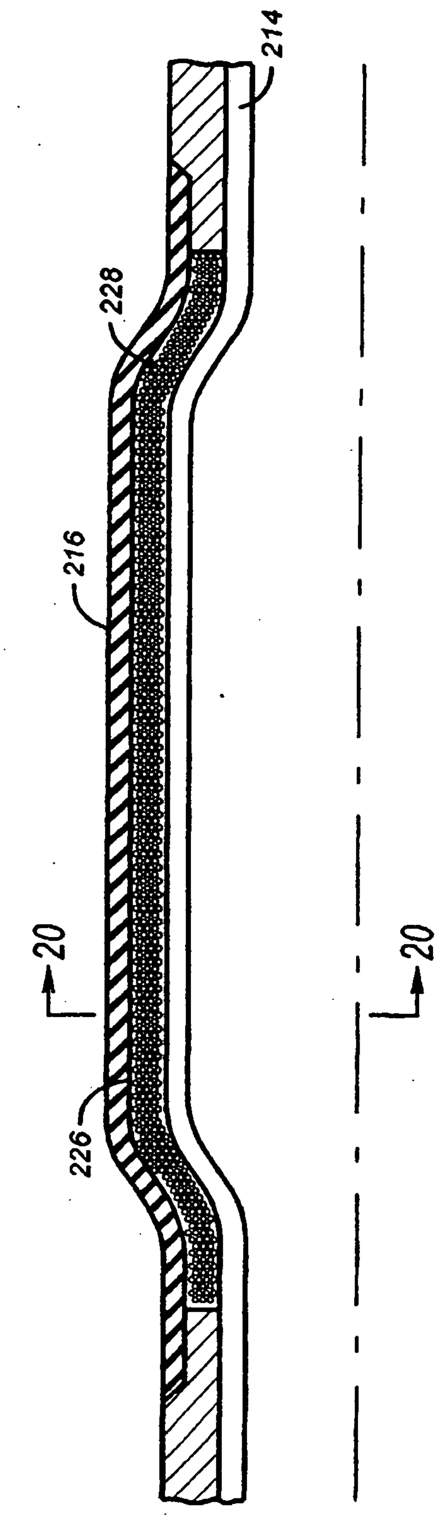


FIG. 19

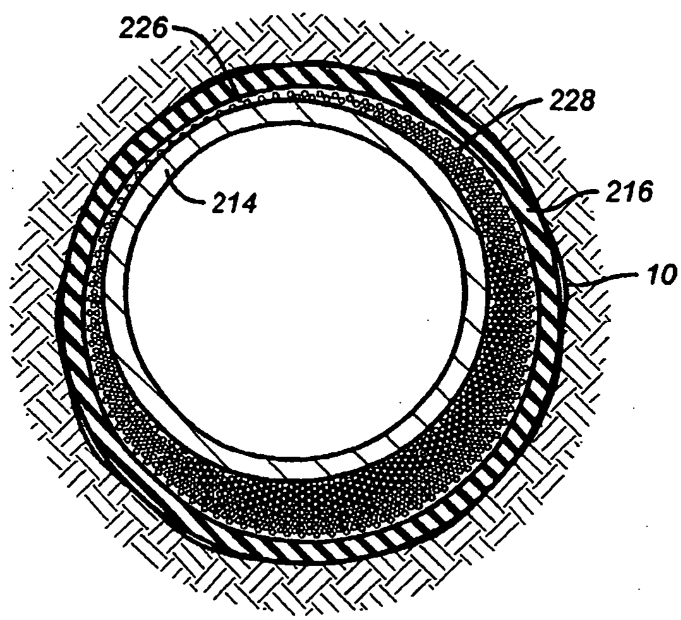


FIG. 20

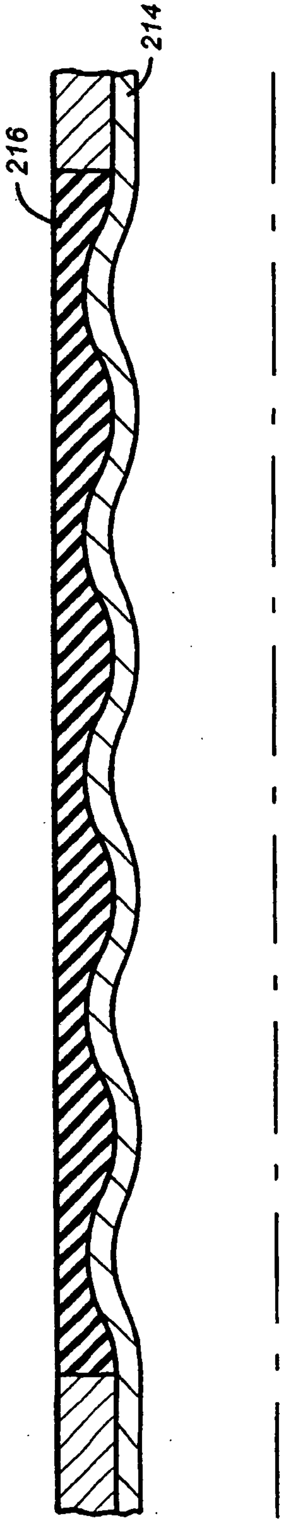


FIG. 21

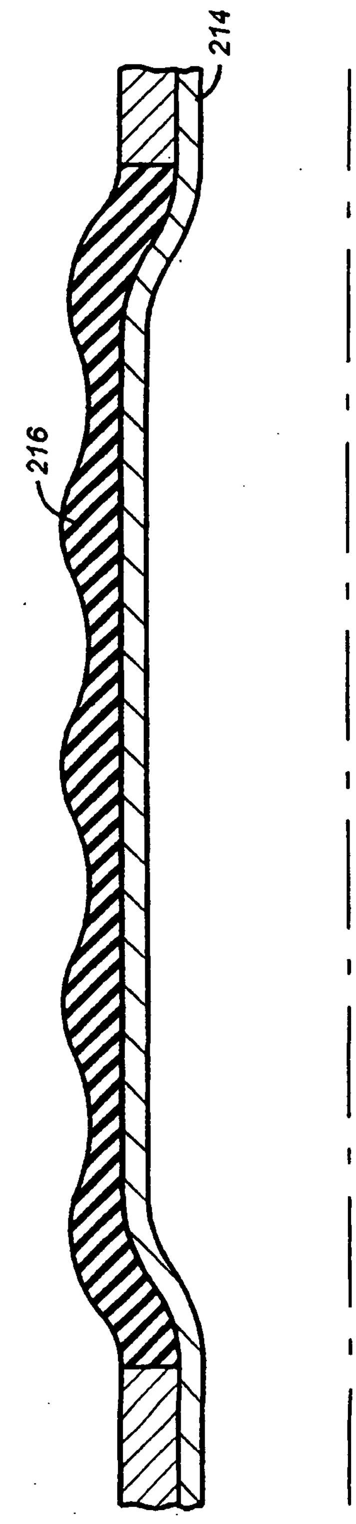


FIG. 22

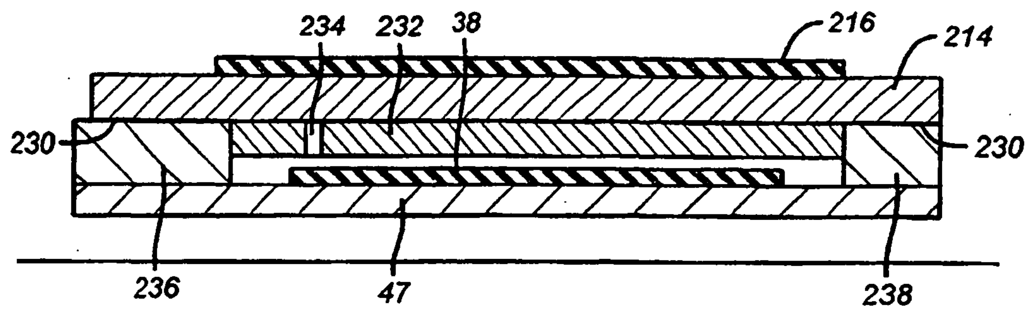


FIG. 23

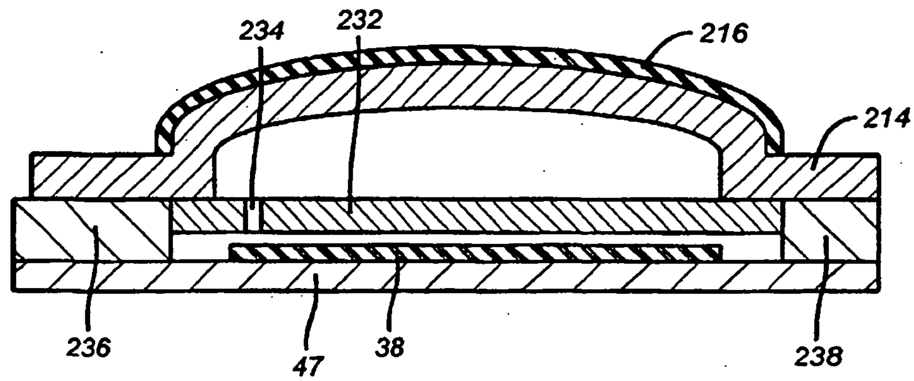


FIG. 24

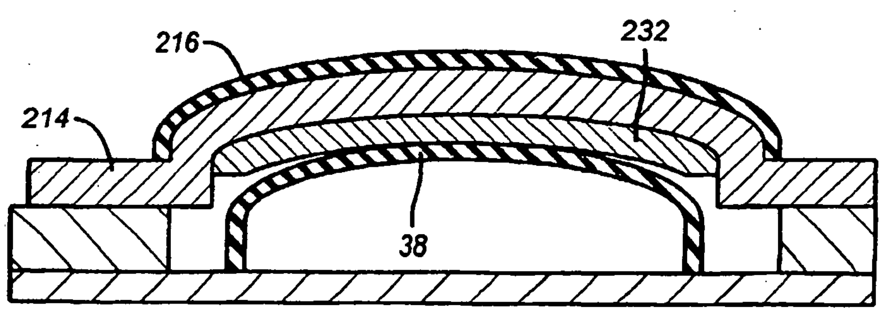


FIG. 25

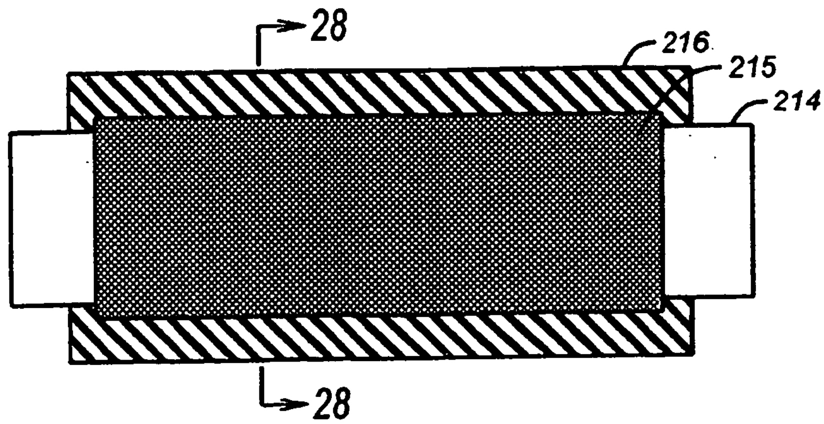


FIG. 26

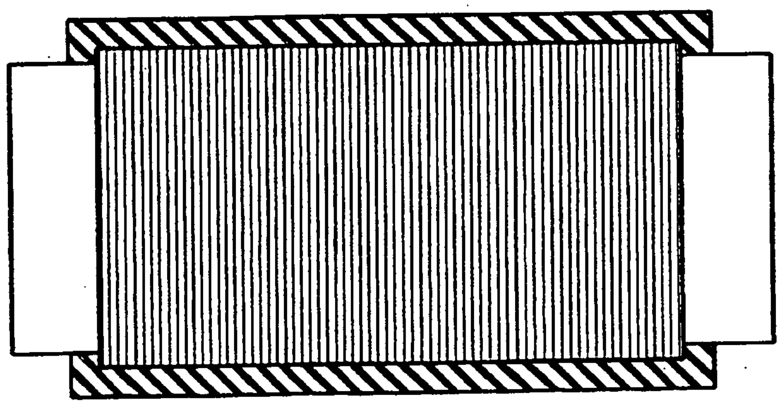

FIG. 27

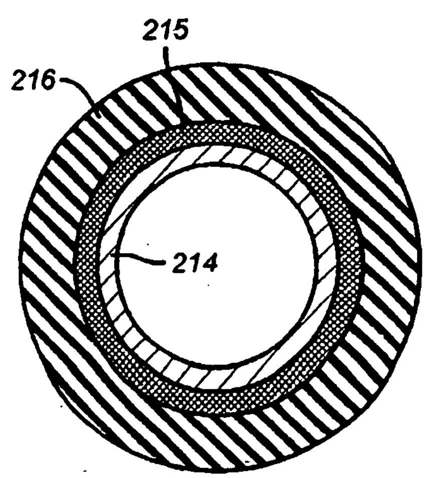


FIG. 28

**TITLE: EXPANDABLE PACKER ISOLATION SYSTEM**

**FIELD OF THE INVENTION**

The field of this invention is one-trip completion systems, which allow for zone isolation and production using a technique for expansion of screens and isolators, preferably in open hole completions.

**BACKGROUND OF THE INVENTION**

Typically zonal isolation is desirable in wells with different pressure regimes, incompatible reservoir fluids, and varying production life. The typical solution to this issue in the past has been to cement and perforate casing. Many applications further required gravel packing adding an extra measure of time and expense to the completion. The cemented casing also required running cement bond logs to insure the integrity of the cementing job. It was not unusual for a procedure involving cemented casing, gravel packing and zonal isolation using packers to take 5-20 days per zone and cost as much or over a million dollars a zone. Use of cement in packers carried with it concerns of spills and extra trips into the well. Frequently fracturing techniques were employed to increase well productivity but cost to complete was also increased. Sand control techniques, seeking to combine gravel packing and fracturing, also bring on risks of unintended formation damage, which could reduce productivity.

In open hole completions, gravel packing was difficult to effectively accomplish although there were fewer risks in horizontal pay zones. The presence of shale impeded the gravel packing operation. Proppant packs were used in open hole completions, particularly for deviated or horizontal open hole wells. Proppant packing involved running a screen in the hole and pumping proppants outside of it. Proppants such as gravel or ceramic beads were effective to control cave-ins but still allowed water or gas coning and breakthroughs. Proppant packs have been used between activated isolation devices such as external casing packers in procedures that were complex, time consuming, and risky. More recently, a new technique which is the subject of a co-pending patent application also assigned to Baker Hughes Incorporated a refined technique has been developed wherein a proppant pack is delivered on both sides of a non-activated annular seal. In this technique the seal can thereafter be activated against casing or open hole. While this technique involved improved zonal isolation, it was still costly and involved complex delivery tools and techniques for the proppant.

Shell Oil Company has disclosed more recently, techniques for expansion of slotted liners using force driven cones. Screens have been mechanically expanded, in an effort to eliminate gravel packing in open hole completions. The use of cones to expand slotted liners suffered from several weaknesses. The structural strength of the screens or slotted liners

being expanded suffered as a tradeoff to allow the necessary expansion desired. When placed in service such structures could collapse at differential pressures on expanded screens of as low as 2-300 pounds per square inch (PSI). Expansion techniques suffered from other shortcomings such as the potential for rupture of a tubular or screen upon expansion. Additionally, where the well bore is irregular the cone expander will not apply uniform expansion force to compensate for void areas in the well bore. This can detract from seal quality. Cone expansion results in significant longitudinal shrinkage, which potentially can misalign the screen being expanded from the pay zone, if the initial length is sufficiently long. Due to longitudinal shrinkage, overstress can occur particularly when expanding from bottom up. Cone expansions also require high pulling forces in the order of 250,000 pounds. Slotted liner is also subject to relaxation after expansion. Cone expansions can give irregular fracturing effect, which varies with the borehole size and formation characteristics.

Accordingly the present invention has as its main objective the ability to replace traditional cemented casing completion procedures. This is accomplished by running isolators in pairs for each zone to be produced with a screen in between. The screen and isolators are delivered in a single trip and expanded down hole using an inflatable device to preferably expand the isolators. The screens can also be similarly expanded using an inflatable tool

or by virtue of mechanical expansion, depending on the application. Each zone can be isolated in a single trip. The completion assembly and the expansion tool can selectively be run in together or on separate trips. These and other features of the invention can be more readily understood by a review of the description of the preferred embodiment, which appears below.

**SUMMARY OF THE INVENTION**

A completion technique to replace cementing casing, perforating, fracturing, and gravel packing with an open hole completion is disclosed. Each zone to be isolated by the completion assembly features a pair of isolators, which are preferably tubular with a sleeve of a sealing material such as an elastomer on the outer surface. The screen is preferably made of a weave in one or more layers with a protective outer, and optionally an inner, jacket with openings. The completion assembly can be lowered on rigid or coiled tubing which, internally to the completion assembly, includes the expansion assembly. The expansion assembly is preferably an inflatable design with features that provide limits to the delivered expansion force and/or diameter. A plurality of zones can be isolated in a single trip.

**DETAILED DESCRIPTION OF THE DRAWINGS**

Figures 1a-d, are a sectional elevation view of the open hole completion assembly at the conclusion of running in;

Figures 2a-d, are a sectional elevation view of the open hole completion assembly showing the upper optional packer in a set position;

Figures 3a-d, are a sectional elevation view of the open hole completion assembly with a zone isolated at its lower end;

Figures 4a-d, are a sectional elevation view of the open hole completion assembly with a zone isolated at its upper end;

Figures 5a-d, are a sectional elevation of the open hole completion assembly in the production mode;

Figure 6 is a sectional elevation view of the circulating valve of the expansion assembly;

Figure 7 is a sectional view elevation of the inflation valve mounted below the circulating valve;

Figures 8a-b are a sectional elevation view of the injection control valve mounted below the circulating valve;

Figures 9a-b are a sectional elevation view of the inflatable expansion tool mounted below the injection control valve;

Figure 10 is a sectional elevation view of the drain valve mounted below the inflatable expansion tool;

Figure 11 a detail of a first embodiment of the sealing element on an isolator in the run in position;

Figure 12 is the view of Fig. 11 in the set position;

Figure 13 is a second alternative isolator seal in the run in position;

Figure 14 is the view of Fig. 13 in the set position;

Figure 15 is a third alternative isolator seal in the run in position featuring end sleeves;

Figure 16 is a detail of an end sleeve shown in Fig. 15;

Figure 17 is the view of Fig. 15 in the set position;

Figure 18 is a fourth alternative isolator seal showing a filled cavity beneath it, in the run in position;

Figure 19 is the view of Fig. 18 in the set position;

Figure 20 is the view taken along line 20-20 shown in Fig. 19;

Figure 21 illustrates a sectional elevation view of an undulating seal on the isolator in the run in position;

Figure 22 is the view of Fig. 21 in the set position;

Figure 23 is another alternative isolator with a wall re-enforcing feature shown in section during run-in;

Figure 24 is the view of Fig. 23 after the mandrel has been expanded;

Figure 25 is the view of Fig. 24 after expansion of an insert sleeve with the bladder.

Figure 26 is a section view of an unexpanded isolator showing travel limiting sleeve;

Figure 27 is the view of Fig. 26 after maximum expansion of the isolator; and

Figure 28 is the view at line 28-28 of Fig. 26.

**DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

Referring to Figs. 1a-d, the completion assembly **C** is illustrated in the run in position in well bore **10**. At its lower end, as seen in Figs. 1d-5d are a wash down shoe **12** and a seal sub **14** both of known design and purpose. Working up-hole from seal sub **14** are a pair of isolators **16** and **18** which are spaced apart to allow mounting a screen assembly **20** in between. Further up-hole is a section of tubular **22** whose length is determined by the spacing of the zones to be isolated in the well bore **10**. Further up-hole is another set of isolators **24** and **26** having a screen assembly **28** in between. Optionally at the top of the completion assembly **C** is a packer **30**, which is selectively settable against the well bore **10**, as shown in Fig. 2a. Those skilled in the art will appreciate that the completion assembly described is for isolation of two distinct producing zones. The completion assembly **C** can also be configured for one zone or three or more zones by repeating the pattern of a pair of isolators above and below a screen for each zone.

The completion assembly **C** can be run in on an expansion assembly **E**. Located on the expansion assembly **E** is a setting tool **32** which supports the packer **30** and the balance of the completion assembly **C** for run in. Ultimately, the setting tool **32** actuates the packer **30** in a known manner. The majority of the expansion assembly **E** is nested within the completion assembly **C** for run in. At the lower end **34** of the expansion assembly **E**, there is engagement into a seal bore **36** located in seal sub

**14**. If this arrangement is used, circulation during run in is possible as indicated by the arrows shown in Figs. 1a-d.

The expansion assembly **E** shown in Figs. 1a-d through 5a-d is illustrated schematically featuring an expanding bladder **38**. The bladder **38** is shown above the seal bore **36** in an embodiment where flow through the expansion assembly E can exit its lower end **34**. In a known manner one or more balls can be dropped to land below the bladder **38** so that it can be selectively inflated and deflated at desired locations. While this is one way to actuate the bladder **38**, the preferred technique is illustrated in Figs. **6-10**. Using the equipment shown in these Figures, the placement of the seal bore **36** will need to be above the bladder **38**, as will be explained below.

At this point, the overall process can be readily understood. The completion assembly **C** is supported off of the expansion assembly **E** for running in to the well bore in tandem on rigid or coiled tubing **40**. The setting tool **32** engages the packer **30** for support. Circulation is possible during run in as flow goes through the expansion assembly **E** and, in the preferred embodiment shown in Fig. 7, exits laterally through the inflation valve **42** at ports **44** which are disposed below a seal bore such as **36**. It should be noted that the inflation valve **42** (see Fig. 7) is disposed above screen expansion tool **47** (see Figs. 9a-b), which comprises the bladder **38**.

During run in, the bladder **38** is deflated and circulation out of ports **44** goes around deflated bladder **38** and out through wash down shoe **14**, or an equivalent lower outlet, and back to the surface through annulus **46**.

The packer **30** is set using the setting tool **32**, in a known manner which puts a longitudinal compressive force on element **48** pushing it against the well bore **10**, closing off annulus **46** (as shown in Fig. 2a). The use of packer **30** is optional and other devices can be used to initially secure the position of completion assembly **C** prior to expansion, without departing from the invention.

The expansion assembly is then actuated from the surface to inflate bladder **38** so as to diametrically expand the lowermost isolator **16**, followed by screen **20**, isolator **18**, and, if present, isolator **24**, followed by screen **28**, and isolator **26**. These items can be expanded from bottom to top as described or in a reverse order from top to bottom or in any other desired sequence without departing from the invention. The expansion technique involves selective inflation and deflation of bladder **38** followed by a repositioning of the expansion assembly **E** until all the desired zones are isolated by expansion of a pair of isolators above and below an expanded screen. The number of repositioning steps is dependent on the length of bladder **38** and the length and number of distinct isolation assemblies for the respective zones to be isolated.

Fig.3c shows the lower screen **20** and the lowermost isolator **16** already expanded. Fig. 4b shows the

upper screen **28** being expanded, while Figs. 5a-d reveal the conclusion of expansion which results in isolation of two zones, or stated differently, two production locations in the well bore **10**. This Figure also illustrates that the expansion assembly **E** has been removed and a production string **50** having lower end seals **52** has been tagged into seal bore **54** in packer **30**. It should be noted that tubular **22** has not been expanded as it lies between the zones of interest that require isolation.

Now that the overall method has been described, the various components, which make up the preferred embodiment of the expansion assembly **E**, will be further explained with reference to Figs. 6-10.

Going from up-hole to down hole the expansion assembly **E** comprises: a circulating valve **56** (see Fig. 6); an inflation valve **42** (see Fig. 7); an injection control valve **58** (see Figs. 8a-b); an inflatable expansion tool **47** (see Figs.9a-b); and a drain valve **60** (see Fig. 10).

The purpose of the circulating valve **56** is to serve as a fluid conduit during the expansion and deflation of the bladder **38**. It comprises a top sub **62** having an inlet **64** leading to a through passage **66**. A piston **68** is held in the position shown by one or more shear pins **70**. Housing 72 connects a bottom sub **74** to the top sub **62**. Seals **76** and **78** straddle opening **80** in housing **72** effectively isolating opening **80** from passage **66**. A ball seat **82** is located on piston **68** to eventually catch a ball (not shown) to allow breaking of shear pins **70** and a shifting of piston 68 to expose opening or openings

80. The main purpose of the circulating valve 56 is to allow drainage of the string as the expansion assembly E is finally removed from the well bore 10 at the conclusion of all the required expansions. This avoids the need to lift a long fluid column that would otherwise be trapped inside the tubing 40, during the trip out of the hole.

The next item, mounted just below the circulating valve 56, is the inflation valve 42. It is illustrated in the run in position. It has a top sub 84 connected to a dog housing 86, which is in turn connected to a bottom sub 88. A body 90 is mounted between the top sub 84 and the bottom sub 88 with seal 92 disposed at the lower end of annular cavity 94. A piston 95, having a groove 96, is disposed in annular cavity 94. Body 90 supports ball seat 97 in passage 98. Body 90 has a lateral passage 100 to provide fluid communication between passage 98 and piston 95. A shear pin or pins 102 secure the initial position of piston 95 to dog housing 86. Body 90 also has lateral openings 104 and 106 while dog housing 86 has a lateral opening 44 near opening 106. At the top of piston 95 are seals 108 and 110 to allow for pressure buildup above piston 95 in passage 98 when a ball (not shown) is dropped onto ball seat 97. Mounted to dog housing 86 are locking dogs 112 which are biased into groove 96 when it presents itself opposite dogs 112. Biasing is provided by a band spring 114.

The operation of the inflation valve 42 can now be understood. During run in, passage 98 is open down to lateral opening 106. Since passage 98 is

initially obstructed in injection control valve **58**, for reasons to be later explained, flow into passage **98** exits the dog housing **86** through lateral openings **106** (in body **90**) and lateral opening **44** (in dog housing **86**). Since opening **44** is below a seal bore (such as **36**) mounted to the completion assembly **C** flow from the surface will, on run in, go through the circulating valve **56** and through passage **98** of inflation valve **42** and finally exit at port **44** for conclusion of the circulation loop to the surface through annulus **46**. Dropping a ball (not shown) onto ball seat **97** allows pressure to build on top of piston **95**, which breaks shear pin **102** as piston **95** moves down. This downward movement allows flow to bypass the now obstructed ball seat **97** by moving seals **108** and **110** below lateral port **104**. At the same time, lateral port **44** is obstructed as seal **116** passes port **106** in body **90**. The movement of piston **95** is locked as dogs **112** are biased by band spring **114** into groove **96**. Pressure from the surface, at this point, is directed into the injection control valve **58**.

The injection control valve **58** comprises a top sub **118** connected to a valve mandrel **120** at thread **122**. Valve mandrel **120** is connected to spring mandrel **124** at thread **126**. Spring mandrel **124** is connected to sleeve adapter **128** at thread **130**. Sleeve adapter **128** is connected to bottom sub **132** at thread **134**. Wedged between valve mandrel **120** and top sub **118** are perforated sleeve **136** and plug **138**. Seal **140** is used to seal plug **138** to valve mandrel **120**. Flow entering

passage **142** from passage **98** in the inflation valve **42** passes through openings **144** in perforated sleeve **136** and through lateral passage **146** in valve mandrel **120**. This happens because plug **138** obstructs passage **142** below openings **144**. Piston **148** fits over valve mandrel **120** to define an annular passage **150**, the bottom of which is defined by seal adapter **152**, which supports spaced seals **154** and **156**. In the initial position, seals **154** and **156** straddle passage **158** in valve mandrel **120**. A pressure buildup in annular passage **150** displaces piston **148** and moves seal **154** past passage **158** to allow flow to bypass plug **138** through a flow path which includes openings **144**, passage **146**, passage **158**, and eventually out bottom sub **132**. At the same time spring **160** is compressed by seal adapter **152**, which moves in tandem with piston **148**. Seals **154** and **156** wind up straddling passage **162** in valve mandrel **120**. This prevents escape of fluid out through passage **164** in seal adapter **152**. Accordingly, fluid flow initiated from the surface will flow through injection control valve **58** after sufficient pressure has displaced piston **148**. Such flow will proceed into inflatable expansion tool **47**. Upon removal of surface pressure, spring **160** displaces seals **154** and **156** back above passage **162** to allow pressure to be bled off through passage **164** to allow bladder **38** to deflate, as will be explained below.

Referring now to Figs. 9a-b, the structure and operation of the inflatable expansion tool **47** will now be described. A top sub **168** is connected to a

mandrel **170** and a bottom sub **172** is connected to the lower end of the mandrel **170**. Bladder **38** is retained in a known manner to mandrel **170** by a fixed connection at seal adapter **174** at its upper end and by a movable seal adapter **176** at its lower end. Seal adapter **176** is connected to spring housing **178** to define a variable volume chamber **180** in which are mounted a plurality of Belleville washers **182**. A stop ring **184** is mounted to mandrel **170** in a manner where it is prevented from moving up-hole. Passages **186** and **187** communicate pressure in central passage **188** through the mandrel **170** and under bladder **38** to inflate it. In response to pressure below the bladder **38**, there is up-hole longitudinal movement of seal adapter **176** and spring housing **178**. Since stop ring **184** can't move in this direction, the Belleville washers get compressed. Outward expansion of bladder **38** can be stopped when all the Belleville washers have been pressed flat. Other techniques for limiting the expansion of bladder **38** will be described below. What remains to be described is the drain valve **60** shown in Fig. **10**. It is this valve that creates the back- pressure to allow bladder 38 to expand.

The drain valve **60** has a top sub **190** connected to an adapter **192**, which is, in turn, connected to housing **194** followed, by a bottom sub **196**. A piston **198** is connected to a restrictor housing **200** followed by a seal ring seat **202**. Restrictor housing **200** supports a restrictor **204**. Spring **206** bears on bottom sub **196** and exerts an up-hole force on piston **198**. Seal **208**

forces flow through restrictor **204** producing back-pressure, which drives the expansion of bladder **38**. Initially flow will proceed through restrictor **204** into passage **210** and around spring **206** and between seal ring seat **202** and seal ring insert **212**. This flow situation will only continue until there is contact between seal ring seat **202** and seal ring insert **212**. At that time flow from the surface stops and applied pressure from surface pumps is applied directly under bladder **38**. One reason to cut the flow from drain valve **60** is to prevent pressure pumping into the formation below, which can have a negative affect on subsequent production. When the surface pumps are turned off, a gap reopens between seal ring seat **202** and seal ring insert **212**. Some under bladder pressure can be relieved through this gap. Most of the accumulated pressure will bleed off through passage **164** in the injection control valve **58** (see Fig. 8a) in the manner previously described.

Those skilled in the art can now see how by selective inflation and deflation of bladder **38** the isolators and screens illustrated in Figs. 1a-d can be expanded in any desired order.

Some of the features of the invention are the various designs for the expandable isolator, such as isolator **26**, as illustrated in Figs. 11-22. It should be noted that the isolator depicted in Figs. 1a-d is not an inflatable packer in the traditional sense. Rather it is a tubular mandrel **214** surrounded by a sealing sleeve **216** wherein inflatable, such as bladder **38**, or other devices are used to expand both

mandrel **214** and sleeve **216** together into the open hole of well bore **10**.

In the embodiments shown in Figs. 11 and 12 the sleeve **216** is shown in rubber. There are circumferential ribs **218** added to prevent rubber migration or extrusion upon expansion. The expanded view is illustrated in Fig. 12.In open hole completions, the ribs **218** dig into the borehole wall. This assures seal integrity against extrusion. Ribs **218** can be directly attached to the mandrel **214** or they can be part of a sleeve, which is slipped over mandrel **214** before the rubber is applied. Direct connection of ribs **218** can cause locations of high stress concentration, whereas a sleeve with ribs **218** mounted to it reduces the stress concentration effect. Ribs **218** can be applied in a variety of patterns such as offset spirals. They can be continuous or discontinuous and they can have variable or constant cross-sectional shapes and sizes.

A beneficial aspect of ribs **39** in bladder **38** (see Fig. 9a) is that their presence helps to reduce longitudinal shortening of mandrel **214** and sleeve **216** as they are diametrically expanded. Limiting longitudinal shrinkage due to expansion is a significant issue when expanding long segments because a potential for a misalignment of the screen and surrounding isolators from the zone of interest. This effect can happen if there is significant longitudinal shrinkage, which is a more likely occurrence if there is a mechanical expansion with a cone.

The expansion techniques can be a combination of an inflatable for the isolators and a cone for expansion of screens. This hybrid technique is most useful for cone expanding long screen sections while the isolators above and below are expanded with a bladder. The isolators require a great deal of force to assure seal integrity making the application of inflatable technology most appropriate. The inflation pressure for a bladder **38** disposed inside an isolator can be monitored at the surface. The characteristic pressure curve rises steeply until the mandrel starts to yield, and then levels off during the expansion process, and thereafter there is a subsequent spike at the point of contact with the formation or casing. It is not unusual to see the plateau at about 6,000 PSI with a spike going as high as 8500 PSI. Use of pressure intensifiers adjacent the bladder **38**, as a part of the expansion assembly **E**, allows the up-hole equipment to operate at lower pressures to keep down equipment costs. The ability to monitor and control inflation pressure can be a control technique to regulate the amount of expansion in an effort to avoid mandrel failure or overstressing the formation. Another monitoring technique for real time expansion is to put strain sensors in the isolator mandrels and use known signal transmission techniques to communicate such information to the surface in real time. Yet another technique for limitation of expansion can be control of the volume of incompressible fluid delivered under the bladder **38**. Another technique can be to

apply longitudinal corrugations to the mandrel **214**, such that the size it will expand to when rounded by an inflatable is known.

Referring now to Figs. 13 and 14, another approach to limiting extrusion of sealing sleeve **216** upon expansion by a bladder **38**, is to put reinforcing ribs **220** in whole or in part at or near the upper and/or lower ends of the sealing sleeve **216**. Their presence creates an increased force into the open hole to reduce end extrusion, as shown in Fig. 14.

In Figs. 15-17, the anti-extrusion feature is a pair of embedded rings **221** that run longitudinally in sleeve **216**. The stiffness of each ring **221** can be varied along its length, from strongest at the ends of sleeve **216** to weaker toward its middle. One way to do this is to add bigger holes **222** closer to the middle of sleeve **216** and smaller holes **224** nearer the ends, as shown in Fig. 16. Another way is to vary the thickness.

In Figs. 18-20, another variation is shown which involves a void space **226** between the mandrel **214** and the sleeve **216**. This space can be filled with a deformable material, or a particulate material, such as proppant, sand, glass balls or ceramic beads **228**. The beneficial features of this design can be seen after there is expansion in an out of round open hole, as shown in Fig. 20. Where there is a short distance to expand to the nearby borehole wall, contact of sleeve **216** occurs sooner. This causes a

displacement of the filler **228** so that the regions with greater borehole voids can still be as tightly sealed as the regions where contact is first made. This configuration, in particular, as well as the other designs for isolators discussed above offers an advantage over mechanical expansion with a cone. Cone expansion applies a uniform circumferential expansion force regardless of the shape of the borehole. The inflate technique conforms the applied force to where the resistance appears. Expansions that more closely conform to the contour of the well bore can thus be accomplished. Use of the void **226** with filler **228** merely amplifies this inherent advantage of expansion with a bladder **38**. Those skilled in the art will appreciate that the shorter the bladder **38**, the greater is the ability of the isolator to be expanded in close conformity with the borehole configuration. One the other hand, a shorter bladder also requires more cycles for expansion of a given length of isolator or screen. Longer bladders not only make the expansion go faster, but also allow for greater control of longitudinal shrinkage. Here again, the ability to control longitudinal shrinkage will have a tradeoff. If the mandrel **214** is restrained from shrinking as much longitudinally its wall thickness will decrease on diametric expansion. Compensation for this phenomenon by merely increasing the initial wall thickness of the mandrel **214** creates the problem of greatly increasing the required expansion pressure.

A solution is demonstrated in Figs. 23-25. In these Figures, the mandrel **214** still has the sleeve **216**. Internally to mandrel **214** is a seal bore **230**, which can span the length of the sleeve **216**. Within the seal bore **230**, the inflatable expansion tool **47** is inserted. The inflatable expansion tool **47** has been modified to have a bladder **38** and an insert sleeve **232** with a port **234** all mounted between two body rings **236** and **238**. Initially, as shown in Fig. 24, fluid pressure expands the mandrel **214** against the borehole through port **234**. Then the bladder **38** is expanded to push the sleeve **232** against the already expanded mandrel **214**(see Fig. 25).

Yet another technique for improving the sealing of an isolator is to take advantage of the greater coefficient of thermal expansion in the sleeve **216** such as when it is made of rubber. If the rubber is pre-cooled prior to running into the well bore it will grow in size as it comes to equilibrium temperature even after it has been inflatably expanded. The subsequent expansion increases sealing load. Thus rather than over-expanding the formation in-order to store elastic energy in it, the use of a mandrel **214** with a thin rubber sleeve **216** allows storage of elastic strain in the rubber itself. Although rubber has been mentioned for sleeve **216** other resilient materials compatible with down hole temperatures, pressures and fluids can be used without departing from the invention.

The screens, such as **28** can have a variety of structures and can be a single or multi-layer arrangement. In Fig.1b, the screen **28** is shown as a sandwich of a 250-micron membrane **240** between inner **242** and outer **244** jackets. These jackets are perforated or punched and the membrane itself can be a plurality of layers joined to each other by sintering or other joining techniques. The advantage of the sandwich is to minimize relative expansion as well as to protect the membrane **240**.

Yet another isolator configuration is visible in Figs. 21-22. Here the mandrel **214** has a wavy configuration one embodiment of which is a circumferential ribbed appearance. The sleeve **216** is applied to have a cylindrical exterior surface. After expansion, as seen in Fig. 22, the mandrel **214** becomes cylindrically shaped while the sleeve takes on a wavy exterior shape with peaks where the mandrel **214** had valleys, in its pre-expanded state.

Yet another issue resolved by the present invention is how to limit expansion of the isolators in a radial direction. Unrestrained growth can result in rupture if the elongation limits of the mandrel **214** are exceeded. Additionally, excessive loads on the formation can fracture it excessively adjacent the isolator. Expansion limiting devices can be applied to the isolator itself or to the fluid expansion tool used to increase its diameter. In one example, the mandrel **214** is wrapped in a sleeve **215** made of a biaxial metal weave before the rubber is applied.

This material is frequently used as an outer jacket for high- pressure industrial hose. It allows a limited amount of diametric expansion until the weave "locks up" at which time further expansion is severely limited in the absence of a dramatic increase in applied force. This condition can be monitored from the surface so as to avoid over-expansion of the isolator.

As an expanding-mandrel packer is radially expanded outwards it is desirable to have a mechanism in place to limit the radial growth of the packer. If the packer is allowed to expand without restraint of some kind it will ultimately rupture once the elongation limit of the mandrel material is exceeded. Also, if the packer is allowed to place an excessive load against an open hole formation wall the formation may be damaged and caused to fracture adjacent to the packer. There needs to be an expansion limiting mechanism in either the packer, such as isolator **16**, or expansion device, such as expansion assembly **E**.

If the expanding-mandrel packer is being expanded using an inflatable packer (i.e. using hydraulic pressure), once the yield point of the material is exceeded and the mandrel deforms plastically, pressure indications of the amount of radial expansion is impossible. Therefore, it is desirable that once a pre-determined level of expansion is obtained there is a pressure indication that would indicate the packer is at its maximum design limit.

An increase in applied pressure would be obtained if at some point the packer is subjected to an increased mechanical force opposing additional expansion.

The expansion of the packer may be limited by wrapping a bi-axial metal weave sleeve over the mandrel (see Fig. 26) prior to adding the sealing medium **216** (i.e. rubber). The bi-axial sleeve **215** will grow circumferentially as the packer mandrel is expanded, however at a pre-determined diameter the bi-axial sleeve will "lock-up"(see Fig. 27), preventing any additional radial expansion of the mandrel without a significant increase in applied radial load from the expansion device. This could give an indication at the surface that the limiting diameter of the packer has been reached, and further expansion is ceased.

The bi-axial mesh sleeve **215** would be fabricated in a tubular shape, and would be installed over the expanding-mandrel **214** during assembly of the packer. The mesh sleeve **215** would be in the un-expanded condition at this time. A rubber sealing cover **216** would then be applied over the bi-axial sleeve **215** to serve as the sealing component as the packer is expanded radially against the open-hole or casing. The assembled packer cross section is shown in Fig. 28.

As the packer is expanded in the borehole, the bi-axial mesh sleeve **215** expands circumferentially

along with the packer mandrel **214**. The rubber cover **216** is also expanding at this time. Once a pre-determined amount of expansion is obtained however the weaved metal fibers in the bi-axial sleeve will reach a configuration where further expansion is not possible, without breaking the fibers in the mesh. This will result in additional resistance to radial expansion, which will be detected by an increase in applied pressure required for additional expansion. At this point attempts at further expansion is ceased.

Fig. 27 shows the condition of the packer after reaching the expansion limit of the packer, as dictated by the maximum diametrical growth limit of the bi-axial mesh sleeve **215**. The fiber orientation in the mesh sleeve is more in a perpendicular orientation to the long axis of the packer than before expansion was started. The amount of expansion possible in these mesh sleeves is dictated by the wrapping pattern used, and can be varied to allow various expansion potentials.

The amount of expansion of bladder **38** can also be limited by regulation of volume delivered to it by measuring the flow going in or by delivering fluid from a reservoir having a known volume. Typically the isolators and screens of the present invention will have to be expanded up to 25%, or more, to reach the borehole. This requires materials with superior ductility and toughness. Some acceptable materials are austenitic stainless steels, such as

304L or 316L,super austenitic stainless steel (Alloy 28), and nickel based alloys (Inconel 825). As much as a 45% elongation can be achieved by using these materials in their fully annealed state. These materials have superior corrosion resistance particularly in chlorides or in sour gas service, although some of the materials perform better than others. Inconel 825 is very expensive which may rule it out for long intervals. In vertical wells with short zones this cost will not normally be an issue.

The sequence of expansion can also have an effect on the overall system performance of the isolators. A desirable sequence can begin with an upper isolator followed by a screen expansion followed by expansion of the lower isolator. Simultaneous expansion of the isolators and screen should be avoided because of the potentially different pressure responses, which, in turn, can cause either under or over expansion of the isolators, which, in turn, can cause inadequate sealing or formation fracturing.

When an isolator, such as **16**, is expanded, the sealing integrity can be checked. This can be accomplished using the expansion assembly **E** illustrated in Figs. 6-10. After expansion of the bladder **38**, which sets isolator **16**, the bladder **38** is allowed to deflate by removal of pressure from the surface. Thereafter, flow from the surface is resumed with bladder **38** still in position inside the now expanded isolator **16**. The injection control valve **58** is opened by flow through it, which

ultimately exits through the drain valve **60**. Due to creation of backpressure by virtue of restrictor **204** (see Fig. 10) the bladder re-inflates inside the expanded mandrel **214** of the isolator **16**. A seal is created between the completion assembly **C** and the expansion assembly **E**. Since there is an exit point at wash down shoe **14** and the isolator **16** is already expanded against the well bore **10**, applied pressure from the surface will go back up the annulus **46** until it encounters the sealing sleeve **216**, which is now firmly engaging the bore hole wall **10**. The annulus **46** is monitored at the surface to see if any returns arrive. Absence of returns indicates the seal of isolator **16** is holding. It should be noted that conducting this test puts pressure on the formation for a brief period. It should also be noted that the other isolators could be checked for leakage in a similar manner. For example, isolator **18** can be checked with bladder **38** re-inflated and flow through the expansion assembly **E**, which exits through screen **20** and exerts pressure against a sealing sleeve **216** of isolator **18**.

As previously mentioned, it may be desirable to combine the inflatable technique with a mechanical expansion technique using a cone expander. The driven cone technique may turn out to be more useful in expanding the screen, since substantially less force is required. Cone expansion is a continuous process and can be accomplished much faster for the screens, which are typically considerably longer than the isolators. When it comes to the isolators,

the cone expansion technique has some serious drawbacks. Since the isolators must be expanded in open hole or casing in order to obtain a seal with a force substantial enough for sealing, greater certainty is required that such a seal has been accomplished than can be afforded with cone expansion techniques. In open hole applications, the exact diameter of the hole is unknown due to washouts, drill pipe wear of the borehole, and other reasons. In cased hole applications, there is the issue of manufacturing tolerances in the casing. If the casing is slightly oversized, there will be insufficient sealing using a cone of a fixed dimension. There may be contact by the sealing sleeve **216** but with insufficient force to hold back the expected differential pressures. On the other hand, if the casing is undersized, the isolator may provide an adequate seal but the amount of realized expansion may be too small to allow the cone driver to pass through. If driving from bottom to top there will be a solid lockup, which prevents removal of the cone driver from the well. If driving from top to bottom the isolator will not be able to expand over its entire length. A solution can be the use of the expansion assembly **E** for the isolator expansion in combination with a cone expansion assembly for the screens. These two expansion assemblies can be run in separate trips or can be combined together in a single assembly, which preferably is run into the borehole together with the completion assembly **C**.

It is known that drilling fluids can cause a drilling-induced damage zone immediately around the well bore **10**. Depending on factors such as formation mechanical properties and residual stresses radial fractures can be extended as much as two feet into the formation to bypass the drilling-induced damage zone. This can be accomplished by over expanding the screens as they contact the well bore. A stable fracture presents little or no danger of migration into the zone sealed by the packers. Thus, for example in an eight inch well bore an expansion pressure of about 2500 PSI yields a fracture radius of about .5 feet, while a pressure of 7600PSI causes a 1 foot radius fracture. Because of the large friction existing between the screen and the well bore wall, multiple radial fractures may be induced in different directions, not necessarily aligned with the maximum horizontal stress direction. Increased fracture density improves well bore productivity.

Those skilled in the art will appreciate that the techniques described above can result in a savings in time and expense in the order of 75% when compared to traditional techniques of cementing and perforating casing coupled with traditional gravel packing operations. The system is versatile and can be accomplished while running coiled tubing because the expansion technique is not dependent on work string manipulation as may by needed for a cone expansion using pushing or pulling on the work string. Expansion techniques can be combined and

can include roller expansion as well as cone or an inflatable or combinations. The expansion assembly **E** can expand both the isolators and the screens. Another expansion device that can be used is a swedge. The preferred direction of expansion is down hole starting from the packer **30** or any other sealing or anchoring device, which can be used in its place. The inflatable technique acts to limit axial contraction when compared to other methods of expansion due to the axial contact constraint between the inflatable and isolator or screen during the expansion process. The sealing sleeve **216** can be rubber or other materials that are compatible with conditions down hole and exhibit the requisite resiliency to provide an effective seal at each isolator. The formulation of the sleeve can vary along its length or in a radial direction in an effort to obtain the requisite internal pressure for sealing while at the same time limiting extrusion. Real time feedback can be incorporated into the expansion procedure to insure sufficient expansion force and to prevent over-stressing. Stress can be sensed during expansion and reported to the surface as the bladder **38** expands. The delivered volume to the bladder **38** can be controlled or the flow into it can be measured. The formation can be locally fractured by screen expansion to compensate for drilling fluid, which can contaminate the borehole wall. Using the isolators with tubular mandrels **214** a far greater strength is realized than prior techniques, which required liners to be slotted to reduce expansion force while sacrificing collapse

resistance. The sandwich screens of the present invention can withstand differential pressures of 2-3000 PSI as compared to other structures such as those expanded by rollers where resistance to collapse is only in the order of 2-300 PSI.

In another expansion technique, the mandrel **214** can be made from material which, when subjected to electrical energy increases in dimension to force the sealing sleeve **216** into sealing contact with the borehole.

The use of an inflatable technique to expand the isolators and screens allows flexibility in the direction of expansion i.e. either up-hole or down-hole. It further allows selective expansion of the screens, using a variety of techniques, followed by subsequent isolator expansion by the preferred use of the expansion assembly **E**.

The length of the inflatable is inversely related to its sensitivity to borehole variation and is directly related to the speed with which the isolator is expanded. The screens can be expanded with bladder 38 to achieve localized or more extensive formation fracturing. Overall, higher forces for expansion can be delivered using the expansion assembly **E** than other expansion techniques, such as cone expansions. The inflatable technique can vary the force applied to create uniformity in fracture effect when used in a well bore with differing hardness or shape variations.

The inflatable expansion can be accomplished using a down hole piston that is weight set or actuated by an applied force through the work string. If pressure is used to actuate a down hole piston, a pressure intensifier can be fitted adjacent the piston to avoid making the entire work string handle the higher piston actuation pressures.

The isolators can have constant or variable wall thickness and can be cylindrically shaped or longitudinally corrugated.

The above description is illustrative of the preferred embodiment and the full scope of the invention can be determined from the claims, which appear below.

Claims:

1. A well completion method for isolating at least one zone, comprising:

running into the wellbore a string with at least one isolator in conjunction with a tool which allows flow from the surrounding formation into the string;

expanding said isolator and said tool in said wellbore.

2. The method of claim 1, comprising:

performing said expanding of said isolator and said tool in a single trip into the wellbore.

3. The method of claim 1, comprising:

running in an anchor with said string;

setting the anchor before said expanding; and

releasing the string from the anchor before said expanding.

4. The method of claim 1, comprising:

running in an expansion assembly comprising an inflatable with said string; and

expanding said at least one isolator at least in part with said inflatable.

5. The method of claim 4, comprising:

selectively deflating and moving said inflatable for repositioning;

continuing expansion of said at least one isolator or tool by re-inflating said inflatable after said repositioning.

6. The method of claim 1, comprising:

forming said at least one isolator from an un-perforated mandrel covered by a resilient sealing sleeve.

7. The method of claim 6, comprising:

expanding said mandrel from its original size; and

using at least a partially annealed material for said mandrel.

8. The method of claim 6, comprising:

limiting the amount of expansion with a device fitted to said mandrel.

9. The method of claim 8, comprising:

using a woven sleeve around said mandrel that locks up after a predetermined amount of expansion of said mandrel as said device.

10. The method of claim 8, comprising:

using a strain sensor as said device;

transmitting, in real time, the sensed strain to the surface; and

determining the amount of expansion from said sensed strain.

11. The method of claim 6, comprising:

providing radially extending members from said mandrel into said resilient sealing sleeve to resist extrusion of said resilient sleeve after expansion of said mandrel.

12. The method of claim 6, comprising:

providing an embedded ring located adjacent at least one end of said resilient sleeve to resist extrusion of said sleeve after expansion of said mandrel.

13. The method of claim 12, comprising:

varying the stiffness of said ring along its length.

14. The method of claim 6, comprising:

providing exterior undulations on said mandrel;

providing a cylindrically shaped outer surface on said resilient sleeve;

converting said cylindrical shape of the outer surface of said resilient sleeve to an undulating shape upon expansion of said mandrel.

15. The method of claim 6, comprising:

providing a void between said mandrel and said resilient sealing sleeve;

placing a deformable material or a particulate material in said void;

using said deformable material or said particulate material to aid said resilient sleeve conform to the wellbore shape on expansion of said mandrel.

16. The method of claim 6, comprising:

pre-cooling said resilient sealing sleeve below ambient temperature before insertion into the wellbore.

17. The method of claim 1, comprising:

circulating through said string during run in;

closing off circulation passages;

building pressure in said string;

using pressure in said string to expand said at least one isolator, at least in part.

18. The method of claim 1, comprising:

providing an inflatable on said string to expand said at least one isolator at least in part.

19. The method of claim 1, comprising:

fully expanding said at least one isolator solely with at least one inflatable.

20. The method of claim 19, comprising:

regulating the volume of incompressible fluid delivered to said inflatable as a way to limit expansion of said at least one isolator.

21. The method of claim 19, comprising:

using a screen as said tool;

expanding said screen against the wellbore wall mechanically.

22. The method of claim 19, comprising:

using a screen as said tool;

expanding said screen with said inflatable.

23. The method of claim 22, comprising:

expanding said at least one isolator and said screen in a single trip with said inflatable.

24. The method of claim 18, comprising:

forming said at least one isolator from an un-perforated mandrel covered by a resilient sealing sleeve;

initially expanding said mandrel with pressure and then completing the expansion with said inflatable.

25. The method of claim 22, comprising:

pressure testing, after expansion, the seal of said at least one isolator through said screen.

26. The method of claim 19, comprising:

performing said expanding of said at least one isolator and said tool in a single trip into the wellbore.

27. The method of claim 26, comprising:

running in an anchor with said string;

setting the anchor before said expanding said inflatable;

releasing the string from the anchor before actuation of the inflatable;

removing said inflatable from the wellbore with said string.

28. The method of claim 18, comprising:

forming at least one of said isolators from an un-perforated mandrel covered by a resilient sealing sleeve;

initially expanding said mandrel mechanically with a cone-type device and then completing the expansion with said inflatable.

29. The method of claim 1, comprising:

expanding said tool into contact with the formation; and

fracturing the formation by said expanding.

30. The method of claim 6, comprising:

expanding said tool into contact with the formation; and

fracturing the formation by said expanding.

31. The method of claim 18 comprising:

expanding said tool into contact with the formation; and

fracturing the formation by said expanding.

32. The method of claim 18, comprising:

providing at least two isolators disposed above and below said tool;

providing at least one screen as said tool;

expanding at least one of said isolators and said screen at least in part with said inflatable.

33. The method of claim 31, comprising:

fracturing the formation by said expanding of said screen.

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**Application No:** GB 0130640.6
**Claims searched:** 1-33

**Examiner:** Nicholas Mole
**Date of search:** 15 April 2002

# Patents Act 1977
# Search Report under Section 17

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): E1F (FJF, FMU, FLW, FJB, FLA)

Int Cl (Ed.7): E21B (43/08, 43/10, 43/14)

Other: Online: WPI EPODOC JAPIO

**Documents considered to be relevant:**

| Category | Identity of document and relevant passage | | Relevant to claims |
|---|---|---|---|
| A | GB 2343691 A | (SHELL) | |
| A | GB 2336383 A | (BAKER HUGHES) | |
| A | EP 0360597 A | (HALLIBURTON) | |
| A, P | US 6263966 B | (HAUT) | |
| A | US 5901789 | (DONELLY) | |

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